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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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VOL. CVII.—No. 2783.] *LONDON: FRIDAY, MAY 2, 1919.* [*Registered at the General Post Office as a Newspaper.*] PRICE 9d. BY INLAND POST ... 11d.

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Page 9, April 18.

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See page 106, April 25. 7263

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See page 15, April 25. 7434

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6920
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See Advertisement page 103.

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CARDIFF WAREHOUSE—132, BUTE ST.
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See Advertisement page 26. 7208

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NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

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See Advertisement page 58, April 11. 2469

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&c., &c. 6844

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Furnace Design (Melting and Heat Treatment).
Practical Pyrometry. CO_2 Recorders.
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See half-page Advertisement page 95, April 18.

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ROYAL CORPS OF NAVAL CONSTRUCTORS.

A Competitive Examination for not less than one POST as PROBATIONARY ASSISTANT CONSTRUCTOR will be held at the Royal Naval College, Greenwich, towards the end of June next.

The Regulations and full particulars of the salary, prospects of promotion, etc., may be obtained from the SECRETARY (C.B.), ADMIRALTY, Great George Street, S.W. 1, to whom intending candidates must submit their names and full particulars of their educational and technical training and practical experience not later than 15th May next.

PRIVATE STUDENTS OF NAVAL ARCHITECTURE.

In conjunction with the above examination, there will be a qualifying examination for the Admission of Private Students of Naval Architecture to the Royal Naval College, Greenwich. Applications for the regulations, etc., should be made as in the case of the examinations for the post of Probationary Assistant Constructors (see above).

Private Students are required to pay a fee of £30 a session whilst at the College. U 347

SOCIETY OF TECHNICAL ENGINEERS.

25, Victoria Street, S.W. 1

A Mass Meeting of the South EASTERN DISTRICT (embracing London and the Home Counties) will be held on THURSDAY, 8th MAY, 1919, at CAXTON HALL, Westminster, at 7.30 p.m.

Well-known engineers will speak on the organization of engineers.

All trained engineers whose work is of a non-manual character are invited to be present.

TICKETS obtainable from Local Secretaries or the above address, or at door.

U 528

Inst. C.E., I. Mech. E., B.Sc., and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.Sac.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 7438

Inst. C.E., Inst. Mech. E., and all Engineering Exams. Correspondence coaching by practical engineers. I.C.H. successes 265 out of 293. Two Bayliss Prizes, "Proxime Accessit." Special features for foreign candidates. Write for booklet, &c.—Address, 7434, Offices of ENGINEERING.

A.M.I.C.E. and A.M.I.M.E. Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 264, Oxford Road, Manchester.

TENDERS.

April 7th, 1919.

Sale by Private Tender.

COMPLETE ALTERNATING CURRENT GENERATING PLANT consisting of:—

One 525 B.HP., and two 300 HP. Carels three-cylinder Diesel Oil Engines with Reavell Compressors, direct-coupled to

Two 215 K.W. and one 525 K.W. Dick Kerr 3-phase 2000 volt.

50 period Alternators with direct-coupled Exciters.

Complete Auxiliary Gear, consisting of Reavell 4-stage Compressor, driven by direct-coupled 2000 volt, 3-phase, 100 HP. Induction Motor, Marble Switchboard with mechanical remote control for three generator and two feeder panels with the usual measuring and synchronising gear. Motor-driven, water circulating and fuel oil pumps, Heenan & Froude Water Cooling Plant for 7000 gallons per hour. Cooling Water and Fuel Oil Tanks, Fuel Oil Storage Tanks of 90 tons capacity and quantity of new and second-hand Spare Parts.

Also One 20 ton Engine Room Crane, 47 ft. span, with hand traverse, and electric hoist; and One 15 ton ditto, hand traverse, hoist 37 ft. 6 in. span.

The whole is in good running order, and adjusted to run on either tar or crude oil.

The plant may be inspected by prospective purchasers by appointment.

Offers will be considered for the whole or part of above plant.—Address, U 32, Offices of ENGINEERING.

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

SALE BY TENDER.

STEEL WORK.

Tenders are Invited for the

following STEEL WORK:—

64 Steel Bowstring ROOF TRUSSES, 55 ft. span; approximate weight 1½ tons each truss.

This steel work is now lying at Messrs. Redpath, Brown's Works, Greenwich, with the exception of a small portion which is lying at Hamble Aerodrome, Hants.

Full particulars, Tender Forms and permits to view, may be obtained from the CONTROLLER, Huts and Building Materials Section, Disposal Board, Artillery Mansions, Victoria Street, S.W. 1.

Telegraphic Address: Hutments, Victoria, London. Telephone: Victoria, 1261. U 416

G. R.

BY DIRECTION OF THE DISPOSAL BOARD.

SALE BY TENDER.

STEEL WORK.

Tenders are Invited for the

following STEEL WORK now lying at the National M.G. Factory, Burton.

Steelwork for Eight Skeleton Framed Buildings, each 75 ft. by 60 ft. wide, with built up stanchions, and rails, roof trusses, with wind braces. Approximate weight 15 to 20 tons each shed.

Full particulars, Tender Forms and permits to view may be obtained from the CONTROLLER, Huts and Building Materials Section, Disposal Board, Artillery Mansions, Victoria Street, S.W. 1.

Telegraphic Address: Hutments, Victoria, London. Telephone: Victoria 1261. U 415

G R

BY ORDER OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

ALTERNATING CURRENT ELECTRIC MOTORS, &c.

For Sale by Public Tender.

The following A.C. MOTORS, 200 volts, 50 cycles, two phase, with Starters and other Accessories, are lying at Daimler Works, Coventry:—

2— 5 HP., by Crompton.
2— 8 HP., by Siemens.
4—15 HP., by Crompton, and Ingleby & Co.
16—20 HP., by Crompton, Ingleby, Phœnix and Siemens.
3—25 HP., by Ingleby.
32—30 HP., by Bruce Peebles, B.T.H., Westinghouse, G.E.C., and Lancashire Dynamo.
8—60 HP., by B.T.H.

The above will be sold as a whole or in part.

All Tenders must be submitted by the 15th May at the latest.

Tender Forms and permits to view can be obtained on application to the CONTROLLER, M.P. (D) Section, Charing Cross Embankment Buildings, London, W.C. 2. U 468

G. R.

BY DIRECTION OF THE DISPOSAL BOARD, MINISTRY OF MUNITIONS.

For Sale by Public Tender,

29 LANCASHIRE & GALLOWAY BOILERS.

LANCASHIRE BOILERS.

Six 30 ft. by 8 ft. 6 in. 120–140 lbs. W.P.
Two 30 ft. by 8 ft. 100 lbs. W.P.
Six 30 ft. by 7 ft. 6 in. 140 lbs. W.P.
Two 30 ft. by 7 ft. 120 lbs. W.P.
Four 28 ft. by 8 ft. 100–120 lbs. W.P.
Two 28 ft. by 7 ft. 150 lbs. W.P.
One 27 ft. by 8 ft. 6 in. 140 lbs. W.P.
Two 27 ft. by 7 ft. 6 in. 150 lbs. W.P.
One 27 ft. by 7 ft. 100 lbs. W.P.
One 26 ft. by 6 ft. 6 in. 110 lbs. W.P.

GALLOWAY BOILERS.

One 28 ft. by 7 ft. 6 in. 100 lbs. W.P.
One 24 ft. by 7 ft. 3 in. 60 lbs. W.P.

These boilers have not been used since inspection by the boiler insurance companies, when they were certified for the working pressures stated above.

Tenders must be submitted by the 13th May.

Tender Form and permit to view may be obtained on application to the CONTROLLER, Machinery and Plant Demobilization, Charing Cross Embankment Buildings, London, W.C. 2. U 444

G. R.

BY DIRECTION OF THE DISPOSAL BOARD,

NATIONAL PROJECTILE FACTORY, TEMPLEBOROUGH, SHEFFIELD.

For Sale by Tender this FREEHOLD FACTORY.

The following is a brief description:—

Situation.—Fronting Main Road and Electric Tram Route from Sheffield to Rotherham.
Within the City of Sheffield, ¼ mile of Tinsley Station, G.C. Rly.

Construction.—The Main Engineering Shop is steel framed with corrugated iron walls, roof part glazed and part corrugated iron. Floor of wood and concrete; length 580 feet, width 400 feet, height 20 feet in the clear. Electric cranes either side of building, area, 234,000 super feet.
Bond Room attached, area 35,340 super feet.
Main Offices, Slab Walls, covered ruberoid, area 8376 super feet.
Main Store, Steel framed, covered corrugated iron, area 5945 super feet.
Mill Wrights' Shop, Stores, Power House, Boiler House, etc.
Additional Buildings, Timber built with corrugated iron walls and corrugated iron or ruberoid roof, comprises:—
Canteen and Lavatories, area 26,833 super feet.
Cleak Room, area 10,563 super feet.
Tool Room, Small Store, Ambulance and Surgery, Garage, Men's and Women's Time Office (Brick built) Lorry Shed, Staff Lunch Room, etc.
Total ground area of buildings, 354,519 super feet.
The Factory was erected by the Government in 1915–16, and has been used for Shell Making.

Area of Land.—20 acres (about) giving large area for extension.

Power and Lighting.—Electric (Corporation Mains).

Heating.—Steam.

Water.—Public Main.

Sidings.—Full gauge connection with the G.C. Railway. Total length 4565 feet.

Office Accommodation for 209 clerks.

Mess Room Accommodation for 1500 persons.

Forms of Tender may be obtained from the DISPOSAL BOARD, Factories Section, Charing Cross Buildings, Embankment, London, W.C. 2. U 282

G. R.

MISCELLANEOUS ENGINEERING STORES.

For Sale by Public Tender,

by direction of the Disposal Board, Ministry of Munitions, SURPLUS STORES now lying at Leicester, consisting of:—

Hydraulic Packing.
"Skefko" Ball Bearings.
Belting (Arundel, Camelata, and Balata).
Belting, Leather—Belt Fasteners.
Electric Globes and Inspection Torches.
Wood Pulleys.
Threadmilling Cutters; Knurling Tools, &c.
Lathe and Drilling Machine Pinions.
Files.
Twist Drills.
Varnish, Turps, Lubricating Oils.
Dies and Taps and Reamers.
Hack Saw Blades.
Overalls and Caps.
Oilskins.
C. I. Castings.
Round B. D. Steel.
Mild Steel.
Caustic Soda.
Scrap Metals and Tools.

Tender Forms and authority to view may be obtained from the CONTROLLER, D.D.S.4, 37/41, Old Queen Street, Westminster, S.W. 1. Last date for receiving Tenders, Monday, May 12th, 1919.

Telegrams: "Explocoma, Parl, London."

Telephone: Victoria 8430; Extension 230.

Applications should state Reference D.D.S.4/Group/8. U 445

G. R.

BY ORDER OF THE DISPOSAL BOARD.

Sale by Tender, Surplus Anti-GAS MATERIAL;

FERROUS and NON-FERROUS WIRE, GAUZE, &c.

The MINISTRY OF MUNITIONS has for DISPOSAL the following Surplus Materials:—

NON-FERROUS.	
31 S.W.G. Brass Wire	6½ tons.
20 S.W.G. Brass Wire	1 cwt.
20 Mesh by 31 S.W.G. Brass Gauze	230,000 sq. ft.
20 Mesh by 31 S.W.G. Copper Gauze	55,000 sq. ft.
FERROUS.	
No. 6 S.W.G. Galvanised Mild Steel Wire in approx. 26 in. lengths	24½ tons.
No. 25 S.W.G. Galvanised Mild Steel Wire	21½ tons.
No. 30 S.W.G. Ungalvanised Mild Steel Wire	1 ton.
18 mesh by 25 S.W.G. Galvanised Mild Steel Gauze	80,000 sq. ft.
7 Mesh by 20 S.W.G. Ungalvanised Mild Steel Gauze	600,000 sq. ft.
7 Mesh by 20 Galvanised Mild Steel Gauze	10,000 sq. ft.
½ in. Cotter Pins	200 gross.

Offers may be made for the whole quantity of each item or for any smaller lot as may be required. Samples may be seen, and Tender Forms obtained on application to the DIRECTOR OF ANTIGAS CONTRACTS, 24, Gordon Square, London, W.C. 1 ("Phone, "MUSEUM 3123").

Tenders must be delivered to the above address not later than Ten a.m., on Saturday, 3rd May, 1919. U 414

TO ENGINEERS, MACHINE TOOL MAKERS, IRONFOUNDERS, AND OTHERS.

An Unique Opportunity is

afforded to persons possessing a small capital, of ACQUIRING as a GOING CONCERN, the PROGRESSIVE and VALUABLE BUSINESS of Engineers, Founders, Machinists, &c., carried on by the CHURNET VALLEY ENGINEERING Co., Ltd., Leek, since 1910, and satisfactory reasons can be given for disposal.

The Works, which are extensive and commodious, are replete with modern and valuable machinery. The premises are well built and in excellent repair. The premises, including the Fixed Plant and Machinery, are held by the Company at a reasonable rent, and have Railway and Canal accommodation within easy accessibility. The Machinery is electrically driven, the Works being lit throughout by Electric Light. The town of Leek is situate 12 miles from Stoke-on-Trent, which is itself the centre of a large manufacturing and industrial area. A good business has been done, and the Company has a high reputation for its 6½ in. centre Lathes and Sud Pumps.

It might be possible to arrange a rental on reasonable terms of the Works and Machinery, or a purchase outright.

Every facility will be given to those desirous of forming a new Company, and the undertaking can be purchased, including the freehold Works, for a sum of about £16,000, exclusive of the Book Debts, which can, however, be taken too if desired.

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APPOINTMENTS OPEN.

CITY OF BIRMINGHAM EDUCATION COMMITTEE.

JUNIOR DAY TECHNICAL (ENGINEERING) SCHOOL.

The Education Committee invite

Applications for the Post of

HEAD MASTER of the above School, to be opened about September next. Candidates must have had experience in teaching and in General Engineering. The maximum salary for the post is fixed at £550 per annum. The commencing salary will be determined by qualifications and experience, with a minimum of £400 per annum. Forms of application may be obtained from the undersigned, and should be returned not later than the 12th MAY.—JNO. ARTHUR PALMER, Secretary of Education, Council House, Margaret Street, Birmingham. U 293

HALIFAX EDUCATION COMMITTEE.

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Applications are Invited for

the following POSITIONS:—

1.—Head of the Mechanical and Electrical Engineering Department. Salary £350 per annum, rising by annual increments of £20 to £500 per annum.
2.—Assistant in the Electrical Engineering Department.
3.—Assistant in the Mechanical Engineering Department.
Salaries of (2) and (3) £200–£250 per annum, according to qualifications and experience.
4.—Assistant Master in the Junior Technical School. Salary according to scale.

Particulars and forms of application, to be returned as early as possible, may be obtained from the Principal. U 488

W. H. OSTLER, Secretary.

The Replanning & Rehousing

of MACEDONIAN TOWNS AND VILLAGES.—WANTED. Twenty-four CIVIL ENGINEERS, SURVEYORS AND ARCHITECTS.—Mr. J. W. MAWSON, Director of Reconstruction for Eastern Macedonia, INVITES APPLICATIONS from Civil Engineers, Surveyors and Architects with town planning or municipal experience, for service on the expert staff now engaged upon the replanning and rebuilding of the towns and villages of Eastern Macedonia. Preference will be given to men of good medical category who have seen service in the East and who hold University degrees or diplomas from the Institute of Civil Engineers, Surveyors' Institute, County and Municipal Engineers, the Royal Institute of British Architects, or the Town Planning Institute. The engagement will be for one year certain, at salaries ranging from £30 to £60 per month, according to age and qualifications, with expenses for the return journey, all contracts to be approved by the Greek Ambassador in London. Application by letter only, giving fullest particulars of age and experience, to be addressed to the undersigned on or before Friday, the 2nd of May. Selected candidates will be interviewed, and if engaged, will be required to leave for Macedonia within 14 days from date of engagement. THOMAS H. MAWSON & SONS, Town Planning Experts, 28, Conduit Street, London, W. U 479

STAFFORDSHIRE EDUCATION COMMITTEE.

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GRAHAM BALFOUR, Director of Education.

County Education Offices, Stafford.
May, 1919. U 502

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Education Dept., Council House, Coventry, 29th April, 1919. U 495

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E. SALTER DAVIES, Director of Education.

25th April, 1919. U 504

AIR MILEAGE OF AEROPLANES INTENDED FOR LONG DISTANCES AND FOR TRANSPORT.

By J. DENNIS COALES, D.Sc., Captain R.A.F.

IN view of the interest, which is now being taken in the possibility of crossing the Atlantic by air, and of using the aeroplane for carrying passengers and freight, it is hoped that the following general treatment of the question of aerial transport may be useful in enabling the limitations of the problem to be determined by making use of the practical data that have been accumulated in the flight trials of modern aeroplanes.

The paper contains an account of the mathematical process by means of which the available data of aeroplane trials and design can be used to determine the maximum possible air mileage in any given case; and, further, the method of arriving at conclusions with regard to what may now be considered the extreme limits of range of aeroplanes, is explained in detail. But although a designer may find it worth while to follow the argument through to the end, it is thought that a brief *résumé* of the conclusions may serve the purpose of those, whose interest is limited to the practical possibilities of aerial transport.

In order that an aeroplane may have the greatest possible air mileage, the following conditions must be complied with:—

1. Its head resistance must be kept by careful design to the smallest possible amount.

2. Its aerodynamic efficiency must under all conditions be as high as possible; and the aeroplane must be flown at an angle of incidence corresponding with its maximum aerodynamic efficiency. This involves the condition that the propellers be designed to yield their maximum efficiencies at the forward speed at which the overall lift-drag ratio has its maximum value. This speed is of the order of 70 m.p.h. to 85 m.p.h., with the aerofoil sections now in common use, and with the wing loadings that are practicable. The maximum aerodynamic efficiencies of modern aeroplanes generally lie between 6 and 7, and in some instances the latter figure is closely approximated to.

3. The horse-power of the engines and the total weight of aeroplane must be so related that the engines develop their normal standard brake horse-power (*i.e.*, run at their normal revolutions per minute) when the aeroplane is flying at its attitude of maximum aerodynamic efficiency.

4. The petrol consumption per standard brake horse-power hour must be as small as possible. The air-mileage diagrams, Fig. 6, on page 560, and Fig. 11, which will appear later in the article, have been worked out on a basis of 0·5 lb. per brake horse-power hour. With other specific petrol consumptions, the air mileage must be changed in inverse proportion to the specific consumption.

5. The weights of all parts of the aeroplane structure and power plant must be reduced to the minima compatible with safety, in order to leave as much weight-carrying capacity for the carriage of petrol and oil.

It would at first sight seem probable, that a large increase of air mileage would be obtained, if an aeroplane could be so loaded up with additional fuel that its initial factor of safety was reduced from, say, 4 to 3. It will be seen on examination of Fig. 11 above mentioned, that in the case of a 25 per cent. reduction of the factor of safety obtained by this means, the maximum possible air mileage is only increased by about 15 per cent.

Another interesting question is, under what conditions of flight is the greatest air mileage obtained when flying against a head wind. The investigation of this problem shows that it only pays to depart from the rule that the flight should be at the attitude of maximum aerodynamic efficiency, when the head wind has a velocity about equal to or greater than half the air speed of the aeroplane when flying at its maximum aerodynamic efficiency. In other words it only pays to provide increased horse-power to gain high speed, when flight is to be made in the face of head winds of about 40 m.p.h. or more.

The following table derived from Figs. 6 and 11 gives the limits of air mileage that should be reached by aeroplanes of the twin-engine type, designed on the best modern lines, with a factor of safety of 4 in the wing trusses; provided that they are flown steadily in the attitude of maximum aerodynamic efficiency, and that this has a value not less than 7. A small deduction of a few miles has to be made to correct for the distance lost during the initial climb to 5,000 ft., as explained in the paper:—

Weight of Freight ÷ Initial Total Weight of Aeroplane.	Weight of Petrol ÷ Initial Total Weight of Aeroplane.	Air Miles.	Height at End of Flight. Feet.
0·0	0·432	2,710	18,600
0·1	0·35	2,100	15,700
0·2	0·27	1,530	13,000
0·3	0·184	1,010	10,100
0·4	0·104	550	7,800

The air speed to which these air mileages correspond would have an initial value of from 70 to 85 miles per hour, depending upon the value of the lift co-efficient at maximum aerodynamic efficiency, and it would fall off slightly during the flight. The greatest falling-off occurs with the longest range of 2,710 miles, in which case the speed at the end of flight is 94·3 per cent. of its initial value. The pounds of total weight per horse-power at the beginning are 29·2.

If a much greater speed is required for flight, then the aerodynamic efficiency will be reduced and therefore also the air mileage. Figs. 6 or 11 can be used to find the air mileage if the aerodynamic efficiency $\eta \frac{L_e}{D_e}$ for the new speed is known, and this can be found by the method of reduction of a trial of the aeroplane described in connection with Fig. 1, page 558. As a rough guide the reduction of the aerodynamic efficiency with increase of velocity can be taken from the following table based on the analysis of a good twin-engine aeroplane:—

Speed ÷ speed at max. aero : efficiency.	Aero efficiency ÷ max. aero : efficiency.
1·0	1·00
1·1	0·965
1·2	0·88
1·3	0·79
1·4	0·72
1·5	0·65
1·6	0·59

It will be shown that the air mileage, which an aeroplane is capable of covering, is dependent upon two main factors:—

1. The average pound-miles per pound of petrol consumed.

2. The ratio of the initial weight of petrol to the total weight of the machine.

The first factor, the pound-miles per pound of petrol, depends upon three subsidiary factors, which are known from practical tests, and which can be given values representing the best results that have been obtained in practise.

These subsidiary factors are:—

(*a*) The specific petrol consumption, or the pounds of petrol consumed by the engine per standard brake horse-power hour.

(*b*) The aerodynamic efficiency of the aeroplane.

(*c*) A quantity depending upon the density of the air, and the fractional loss of engine horse-power with height.

The second main factor, a function of the ratio of the initial weight of petrol to the total weight of machine, is limited by the proportion of freight to be carried, and by the proportion, which the weight of the structure generally, must bear to the total weight of aeroplane, in order that a sufficient margin of strength may be preserved.

In this way we can make an estimate of the maximum air mileage, which the perfection of modern aeroplane design renders possible for a machine with any given proportion of freight.

Before proceeding to the main problem it may be well to indicate briefly the method of reduction of aeroplane trials, which is necessary to arrive at the aerodynamic efficiency of any aeroplane, the suitability of which for aerial transport is to be considered.

The following symbols will be required:—

List of Symbols.

- W = total weight of aeroplane in pounds.
- L_e = overall lift coefficient of aeroplane.
- D_e = overall drag coefficient.
- ρ = relative air density.
- η = airscrew efficiency.
- H = standard brake horse-power of engine, *i.e.*, brake horse-power at normal pressure and temperature.
- $f(\rho)$ = height horse-power correction factor, *i.e.*, the factor by which the standard horse-power at normal pressure and temperature must be multiplied to obtain the horse-power for the same revolutions per minute at a height where the relative density is ρ. (See Fig. 2.)
- V = forward speed in miles per hour.
- w = loading of aeroplane in pounds per square foo of wing area.
- p = the consumption of petrol in pounds per brake horse-power hour at normal temperature and pressure.
- E = standard horse-power per 1,000 lb. weight of aeroplane.
- m = pound-miles per pound of petrol.
- n = engine revolutions per minute.
- x = air miles flown by aeroplane.
- r = ratio of initial weight of petrol to initial total weight of aeroplane.
- A = wing area in square feet.
- q = loading at any time ÷ initial loading.

The drag of an aeroplane in pounds $= W\left(\frac{D_e}{L_e}\right)$.

The foot-pounds per second of level flight $= W\left(\frac{D_e}{L_e}\right) \times V \times 1.466$.

The net horse-power provided by the airscrew $= \eta H f(\rho)$.

Where $f(\rho)$ is the height horse-power correction factor at the height at which the aeroplane is flying.

The foot-pounds per second provided by the airscrew $\eta H \times 550 \times f(\rho)$

Hence:

$$\eta H f(\rho) \times 550 = W\left(\frac{D_e}{L_e}\right) V \times 1{\cdot}466$$

$$\text{or} \quad V = E f(\rho) \times \left(\eta \frac{L_e}{D_e}\right) \times 0{\cdot}375 \quad . \quad (1)$$

Here $\eta \frac{L_e}{D_e}$ is termed the aerodynamic efficiency of the machine, and at a given height and with a given engine horse-power the speed in level flight is proportional to the aerodynamic efficiency.

E is the standard horse-power per 1,000 lb. weight of aeroplane, and V is the speed in miles per hour.

If we suppose that the machine is flown at a height, where $\rho = 1$, with a loading of 1 lb. per square foot of wing area, but with the same attitude as when flown in air of relative density ρ and with loading w; then its speed will be given by $V\sqrt{\frac{\rho}{w}}$, because $V\sqrt{\frac{\rho}{w}} = \frac{14}{\sqrt{L_e}}$, and L_e is constant if the attitude is unchanged.

And further by equation (1) the actual horse-power required will be $E f(\rho)\sqrt{\frac{\rho}{w}}$ for we have:—

$$V\sqrt{\frac{\rho}{w}} = E f(\rho)\sqrt{\frac{\rho}{w}} \times \eta \frac{L_e}{D_e} \times 0{\cdot}375 \quad (2)$$

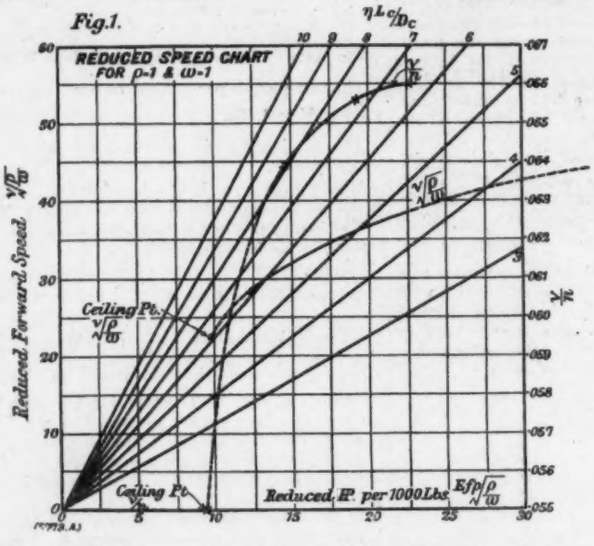
A series of observations of level flights connecting speed and horse-power per 1,000 lb. at various heights, can therefore be reduced to their equivalent values for a standard height where $\rho = 1$ and a standard loading of unity, by multiplying each V and $E f(\rho)$ by the corresponding values of $\sqrt{\frac{\rho}{w}}$.

When these values of $V\sqrt{\frac{\rho}{w}}$ and $E f(\rho)\sqrt{\frac{\rho}{w}}$ are plotted against each other a curve is formed as in Fig. 1, which gives the reduced performance of a machine for a range of different attitudes. If successive constant values are given to the aerodynamic efficiency $\eta \frac{L_e}{D_e}$ in equation (2) straight lines may be drawn on the chart called constant $\eta \frac{L}{D}$ — lines. These straight lines give the reduced horse-power per 1,000 lb. required to produce any desired reduced speed in machines having the aerodynamic efficiency marked on the lines. The reduced curve obtained from the trial cuts across these lines, and it will be seen that the $\eta \frac{L_e}{D_e}$ of the machine rises to a maximum at a value of $V\sqrt{\frac{\rho}{w}}$ which is associated with the best climb. This point will, however, not be dwelt on here,

but it should be remarked that in all modern machines, which have been designed for war purposes, the speed corresponding with maximum $\eta \frac{L_e}{D_e}$ is considerably below the top speed of the machine. All points on the reduced curve correspond with level speeds of the machine. If a point is taken on the chart, which lies below the curve, the horse-power corresponding to it is more than that required to produce the speed to which it corresponds, and the machine will climb, in a similar way a point taken above the curve represents a condition in which the machine will lose height.

It will, perhaps, help the understanding of Fig. 1, if an example is given of its use. Suppose it is desired to find the horse-power required to make a machine of 3,000 lb. weight, and having a wing area of 400 sq. ft., fly at a speed of 120 miles an hour at a height of 10,000 ft., the machine being supposed to have the same aerodynamic qualities as that for which Fig. 1 has been drawn.

Fig. 1.



We have loading W = 7·5 lb. per square foot. $\rho = 0{\cdot}74$, $f(\rho) = 0{\cdot}688$. Therefore

$$V\sqrt{\frac{\rho}{w}} = 120 \times \sqrt{\frac{0{\cdot}74}{7{\cdot}5}} = 37{\cdot}7$$

From Fig. 1 we find corresponding with this value of $V\sqrt{\frac{\rho}{w}}$

$$E f(\rho)\sqrt{\frac{\rho}{w}} = 21{\cdot}5$$

and therefore—

$$E = \frac{21{\cdot}5}{0{\cdot}688} \times \sqrt{\frac{7{\cdot}5}{0{\cdot}74}} = 99{\cdot}4$$

E being the horse-power per 1,000 lb., the standard horse-power required to fly the machine under the condition named is $99{\cdot}4 \times 3 = 298$ and the actual horse-power to be given by the engine at a height of 10,000 ft. is $298 \times f(\rho) = 205$ h.p.

The aerodynamic efficiency of the aeroplane flying at the speed of 120 miles per hour is given by the point $V\sqrt{\frac{\rho}{w}} = 37{\cdot}7$, $E f(\rho)\sqrt{\frac{\rho}{w}} = 21{\cdot}5$ on the chart, and is 4·7.

The climb trials of an aeroplane can be reduced in a similar way, but it is not possible to draw straight lines on the chart for constant $\eta \frac{L_e}{D_e}$. The reduced curve connects values of $E f(\rho)\sqrt{\frac{\rho}{w}}$ with $v\sqrt{\frac{\rho}{w}}$, v being the rate of climb in feet per minute.

Pound-miles per pound of petrol consumed.—Let p be the pounds of petrol consumed per standard brake horse-power hour, *i.e.*, the pounds per brake horse-power hour at normal air density, where $\rho = 1$, and let it be assumed that proper altitude control of the throttle is provided.

Considering equation (1), E is the standard horse-power per 1,000 lb., and therefore the petrol consumed per hour at a height, where $\rho = 1$, will be $E.p.$ lb., and with proper altitude control of the throttle the consumption per 1,000 lb. carried, at a height where the relative density is ρ, will be $E.p.\rho$ lb. per hour. Now, since V is the speed in miles per hour, the consumption in pounds of petrol per mile $= \frac{E.p.\rho}{V}$ per 1,000 lb. of total weight.

We therefore have :—

Pounds of petrol consumed per pound mile $= \frac{E.p.\rho}{1000\,V}$

Reciprocally :—

The Pound miles per pound of petrol $= \frac{1000\,V}{E.p.\rho}$

Substituting the value of V from equation (1) we have

$$\text{Pound miles per pound of petrol} = \frac{1}{p} \cdot \eta \frac{L_e}{D_e} \cdot \frac{f(\rho)}{\rho} \times 375 \quad . \quad . \quad (3)$$

This quantity will be denoted by the letter m.

The value of m is easily calculated from the practical data provided by engine and aeroplane trials. p, the pounds per standard brake horse-power hour of petrol, depends upon the throttle opening as well as upon the type and design of engine.

For well-designed water-cooled aeronautical engines at full throttle and normal brake horse-power p is generally very close to 0·5 lb. $\eta \frac{L_e}{D_e}$ is obtained for any given condition of level flight by simple reduction from aeroplane trials, as indicated above in connection with Fig. 1.

$\frac{f(\rho)}{\rho}$ is determined by the height of flight, the values of $f(\rho)$ being obtained with sufficient accuracy from the mean curve of its values plotted against height given in Fig. 2.

To make the meaning of m quite clear, suppose that its value in a particular case is 4,100. Then, if the aeroplane weighs 2,000 lb., it will travel $\frac{4{,}100}{2{,}000}$ or 2·05 miles per pound of petrol consumed, or, in other words, $2{\cdot}05 \times 7{\cdot}3 = 15$ miles per gallon.

In order that the range of an aeroplane may be a maximum, it is necessary that the aeroplane be so flown that the value of m has at all times its maximum possible value. For m to be a maximum :—

p must be as small as possible, a condition which generally requires full opening of the throttle.

$\eta \frac{L_e}{D_e}$ must be as large as possible. The aeroplane must be flown at an attitude corresponding with the highest value of its overall lift-drag ratio, and the airscrew must develop its highest efficiency at the speeds associated with the maximum $\frac{L_e}{D_e}$. With the wing sections now in use these speeds are generally those at which the best climb is carried out, and are not very much greater than the landing speeds. They cannot, therefore, be very high speeds.

$\frac{f(\rho)}{\rho}$ The maximum value of this is unity, and occurs at ground level or near the ground. To maintain the product $\eta \frac{L_e}{D_e} \times \frac{f(\rho)}{\rho}$ at its maximum possible value, it would be necessary to fly near the ground at heights not exceeding about 1,000 ft. But the consumption of petrol causes the weight of the machine to continually diminish, and in order that it may be kept flying at a low height, it will be necessary to throttle the engine, a procedure which tends to increase the specific petrol consumption p.

On the other hand, if the machine is allowed to climb gradually as its weight decreases, the throttle being kept full open, the value of p will remain at its minimum value, whilst $\frac{f(\rho)}{\rho}$ diminishes from its maximum value of unity. But $\frac{f(\rho)}{\rho}$ diminishes very slowly with increasing height, and it is probable that the pound-miles per pound of petrol will maintain its highest series of values during a flight if :—

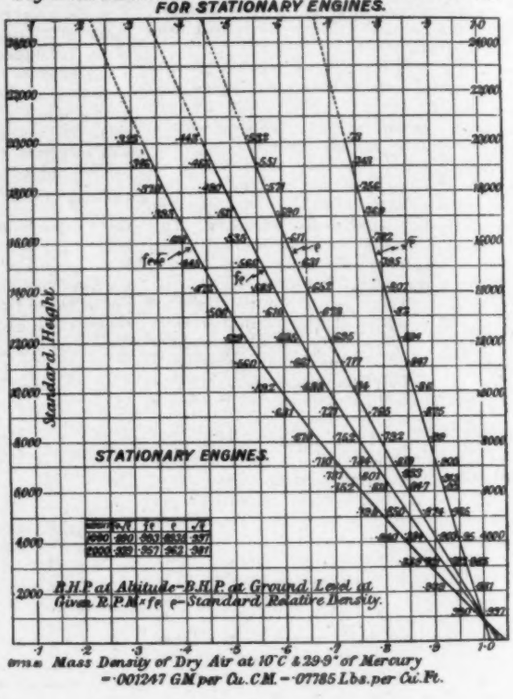
1. The attitude of the machine is kept to that corresponding with its maximum $\eta \frac{L_e}{D_e}$.

2. Its initial weight is such that its engines develop normal brake horse-power at ground level with full throttle opening, normal brake horse-power in good design being that at which p is a minimum.

3. The engine is run at full throttle during the flight and altitude control of the mixture is provided.

It will be seen in what follows that under these circumstances the standard horse-power of the engine will only diminish by about 5 per cent. in a flight of about 2,000 miles, and that, therefore, the specific petrol consumption will remain practically unaltered at its initial value p, unless it be affected by other circumstances, such as wear of engine parts, which cannot be taken into account in this consideration of the problem.

Fig. 2. AIR DENSITY & ENGINE H.P. CORRECTION FACTORS. FOR STATIONARY ENGINES.


Standard Height
STATIONARY ENGINES.
B.H.P. at Altitude ÷ B.H.P. at Ground Level at Given R.P.M. = fe = Standard Relative Density.
Mass Density of Dry Air at 10°C & 29·9" of Mercury
= ·001247 G.M. per Cu. C.M. = ·07785 Lbs. per Cu. Ft.

The latter conditions of flight will be assumed in working out the relations giving the maximum ranges of aeroplanes, and particularly that the machine is so controlled that it always flies at a constant $\eta \frac{L_e}{D_e}$ which for greatest range should have its maximum value. The engine will be adjusted to full throttle, and the throttle opening will not be varied throughout the flight, but the altitude control will be supposed adjusted to keep the mixture constant. Under these conditions, the aeroplane will very gradually climb higher and higher till at the end of a long flight of some thousands of miles it will have reached a height of 20,000 to 25,000 ft. Throughout the whole flight the advance per revolution of the airscrew will be constant.

In what follows the size of the engine and weight of aeroplane will be presumed to be so related that, at the start, normal standard horse-power will be required of the engine, and to keep the problem general in its application, the engine horse-power and its r.p.m. will be stated as ratios of their normal values. The range will be reckoned from the point at which the aeroplane reaches 5,000 ft., because, in a flight of some thousands of miles, the distance travelled during climb to this height is small compared with the total air miles.

Fig. 3 is a generalised engine power curve derived from an average curve of a series of 360 h.p. engines. This curve will be much the same for all stationary engines in contradistinction to rotary engines.

The Relation between the Pound-Miles per Pound of Petrol during flight and the change of Loading by Consumption of Petrol.—During the gradual rise of the machine from the starting point in "level" flight, the value of m the pound-miles per pound of petrol will slowly diminish. When the height at which "level" flight is to begin is settled, general curves showing the variation of m in terms of the fractional diminution of loading can be calculated for various assumed values of the aerodynamic efficiency. Such curves are shown in Fig. 5, and the method of obtaining them will now be explained.—It can be shown (see Fig. 1), that to every attitude of an aeroplane in flight there corresponds a definite value of the advance per revolution of the airscrew, or the ratio $\frac{V}{n}$; and also a definite value of $V\sqrt{\frac{\rho}{w}}$. Consequently if the latter quantity is divided by the former we find that there is also a definite value of $n\sqrt{\frac{\rho}{w}}$, when n = r.p.m. of engine or airscrew, w the loading of the aeroplane in pounds per square foot of wing area, and ρ the relative density at the height of flight. Since in the present case the attitude of the machine is kept constant throughout its flight $n\sqrt{\frac{\rho}{w}}$ is also constant.

Let n_0, ρ_0 and w_0 be the values of the component factors at the start at 5,000 ft., then at any point in the flight

$$n\sqrt{\frac{\rho}{w}} = n_0\sqrt{\frac{\rho_0}{w_0}}$$

or

$$\sqrt{\rho} = \frac{\sqrt{\frac{w}{w_0}}}{\frac{n}{n_0}} \times \sqrt{\rho_0} \quad . \quad . \quad (4)$$

Similarly,

$$V\sqrt{\frac{\rho}{w}} = V_0\sqrt{\frac{\rho_0}{w_0}}$$

and

$$\frac{V}{V_0} = \frac{\sqrt{\frac{w}{w_0}}}{\sqrt{\frac{\rho}{\rho_0}}} \quad . \quad . \quad . \quad . \quad (5)$$

It is also clear from Fig. 1 that in flight with $\eta \frac{L_e}{D_e}$ constant, *i.e.*, with constant attitude $E f(\rho) \times \sqrt{\frac{\rho}{w}}$ is also constant.

Therefore:—

$$E f(\rho)\sqrt{\frac{\rho}{w}} = E_0 f(\rho_0)\sqrt{\frac{\rho_0}{w_0}}$$

but

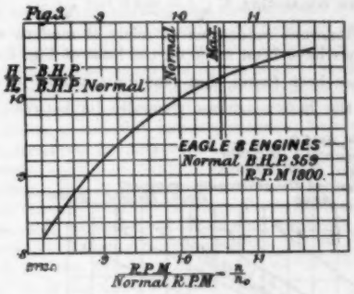
$$\frac{E}{E_0} = \frac{H}{H_0} \times \frac{W_0}{W} \times \frac{A}{A} \times \frac{1000}{1000}$$

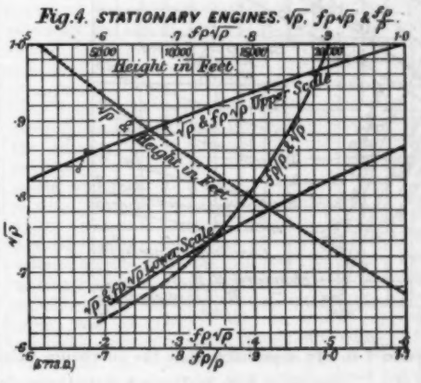
A being wing area in square feet and H standard brake horse-power.

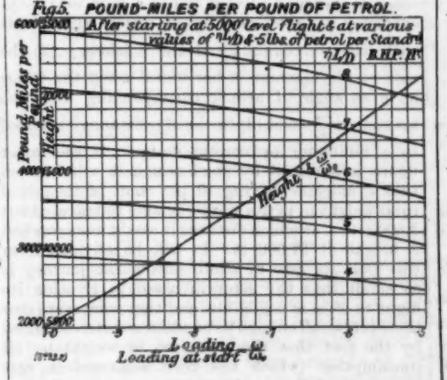
Therefore:—

$$\frac{E}{E_0} = \frac{\frac{H}{H_0}}{\frac{w}{w_0}}$$

(w being loading in pounds per square foot of wing area.)







By substitution we find:—

$$f(\rho)\sqrt{\rho} = \frac{\left(\frac{w}{w_0}\right)^{\frac{1}{2}}}{\frac{H}{H_0}} \times f(\rho_0)\sqrt{\rho_0} \quad . \quad (6)$$

Fig. 4 shows a standard curve for stationary engines connecting $f(\rho)\sqrt{\rho}$ and $\sqrt{\rho}$.

By means of this curve and the engine curve Fig. 3 and equations (4) and (6) we can determine the values of $f(\rho)$, ρ, $\frac{H}{H_0}$ and $\frac{n}{n_0}$ corresponding with that moment of the aeroplane's flight at which its loading w is a given fraction of its initial loading w_0. And having so found $f(\rho)$ and ρ we determine the corresponding pound-miles per pound of petrol from equation (3), if we know the value of $\eta \frac{L_e}{D_e}$ for the aeroplane.

To make this clear the following example will serve:—

At 5,000 ft. $\sqrt{\rho_0} = 0.935$, $f(\rho_0)\sqrt{\rho_0} = 0.795$ on the standard curve Fig. 4.

It is required to find the values of $f(\rho)$, ρ, and $\frac{H}{H_0}$, when the ratio $\frac{w}{w_0} = 0.8$.

We have

$$f(\rho)\sqrt{\rho} = \frac{(0.8)^{\frac{1}{2}} \times 0.795}{\frac{H}{H_0}} = \frac{0.569}{\frac{H}{H_0}} \quad . \quad (4a)$$

and

$$\sqrt{\rho} = \frac{(0.8)^{\frac{1}{2}} \times 0.935}{\frac{n}{n_0}} = \frac{0.836}{\frac{n}{n_0}} \quad . \quad (4a)$$

	$\frac{H}{H_0}$	$\frac{n}{n_0}$	$f(\rho)\sqrt{\rho}$	$\sqrt{\rho}$
Then using these relations:—	1	1	0·569	0·836
And taking $\sqrt{\rho} = 0.86$ calculate $\frac{n}{n_0} = 0.972$, and read	0·983	0·972	0·578	0·86
$\frac{H}{H_0}$ from the engine curve and calculate $f(\rho)\sqrt{\rho}$ from the first of the above relations	0·988	0·98	0·576	0·859

The values of $f(\rho)\sqrt{\rho}$ and $\sqrt{\rho}$ from the first two rows are plotted on the standard $f(\rho)\sqrt{\rho}$ curve as shown in Fig. 4, and when joined the intersection gives the true values in the third row of the above table. Then by using (4*a*) and (6*a*) the definite values of $\frac{n}{n_0}$ and $\frac{H}{H_0}$ are calculated. Finally, from the curve connecting $\sqrt{\rho}$ and $f(\rho)/\rho$ we find the value of the latter to be 0·928.

Now suppose analysis has shown that the maximum $\eta\left(\frac{L_e}{D_e}\right)$ of the machine is 6. Then taking 0·5 lbs. per brake horse-power hour as the specific consumption of the engine we find that the pound miles per pound of petrol are:

$$m = \frac{1}{0.5} \times 6 \times 0.928 \times 375 = 4180, \text{ when } w/w_0 = 0.8$$

and the height of the aeroplane as given by the usual standard density curve is 10,700 ft. in a standard atmosphere, since $\sqrt{\rho} = 0.853$.

TABLE I.

q	$f(\rho)\sqrt{\rho}$	$\sqrt{\rho}$	$\frac{f(\rho)}{\rho}$	$\frac{H}{H_0}$	$\frac{n}{n_0}$	Height (Feet).
1·0	0·795	0·935	0·972	1·00	1·00	5,000
0·9	0·682	0·895	0·952	0·995	0·989	7,800
0·8	0·576	0·853	0·928	0·988	0·980	10,500
0·7	0·485	0·808	0·901	0·980	0·968	13,900
0·6	0·382	0·763	0·863	0·968	0·948	17,400
0·5	0·296	0·715	0·815	0·949	0·924	21,200
0·4	0·221	0·666	0·749	0·909	0·888	25,000

TABLE II.

Values of m, with $p = 0.5$ lb. per Standard Brake Horse-Power Hour.

q	For $\eta\frac{L_e}{D_e}$ =	8	7	6	5	4	3
1·0		5,830	5,100	4,375	3,642	2,917	2,188
0·9		5,710	5,000	4,280	3,570	2,855	2,140
0·8		5,570	4,870	4,180	3,480	2,785	2,090
0·7		5,410	4,730	4,055	3,380	2,702	2,028
0·6		5,180	4,530	3,880	3,240	2,590	1,942
0·5		4,890	4,280	3,664	3,055	2,443	1,833
0·4		4,490	3,930	3,370	2,807	2,245	1,685

Table I gives the values of

$$f(\rho)\sqrt{\rho},\ \sqrt{\rho},\ \frac{f(\rho)}{\rho},\ \frac{H}{H_0},\ \frac{n}{n_0}$$

and height worked out as previously described for values of the loading ratio q varying from 1 to 0·4, the flight being supposed to start at 5,000 ft.

Table II gives values of m the pound miles per pound of petrol, calculated by means of equation (3), for various values of $\eta\frac{L_e}{D_e}$ for each of the values of the loading ratio q in Table I. These values are plotted in Fig. 5.

The Range or Air Mileage of an Aeroplane with a given ratio of petrol to total weight at the start. It will be assumed for simplicity that the starting point is taken at the end of the initial climb.

Let w be the loading in pounds per square foot, after the aeroplane has travelled x miles from the

starting point. Then its weight is $w \times A$ pounds; and the miles per pound of petrol, that it is then capable of are $\frac{m}{w\,A}$.

Let Δx be the miles travelled whilst the loading changes by an amount Δw, which corresponds with a consumption of petrol of $A.\Delta w$ pounds. We therefore have:

$$\Delta x = -\frac{m}{w\,A} \times A\,\Delta w.$$

and

$$\frac{d\,x}{d\,w} = -\frac{m}{w} \quad . \quad . \quad . \quad (7)$$

The negative sign being used because as x increases w diminishes.

Let w_0 = the loading of the aeroplane at the starting point and let $\frac{w}{w_0}$ be called q, *i.e.*, the ratio of the loading after travelling x miles to the initial loading. Then by substitution in (7):

$$\frac{d\,x}{d\,q} = -\frac{m}{q} \quad . \quad . \quad . \quad (8)$$

and the total range in miles is given by:—

$$x = -\int_1^q \frac{m}{q}\,.\,d\,q \quad . \quad . \quad (9)$$

If m the pound miles per pound of petrol were constant, then the Air Mileage would be:—

$$x = 2{\cdot}3\,m \log_{10}\frac{1}{q} \quad . \quad . \quad (10)$$

For rough calculations an average value of m may be taken and this formula used to calculate the air miles.

For example suppose that the aerodynamic efficiency of the aeroplane $\left(\eta\,\frac{L_e}{D_e}\right) = 6$, and it is required to find its range when the initial weight of petrol is 40 per cent. of the total weight of the machine, then q at the start is 1, giving $m = 4375$, and at the end $q = (1 - 0{\cdot}4) = 0{\cdot}6$ giving $m = 3880$. The mean value of m is therefore 4127, and the range in miles is $x = 2{\cdot}3 \times 4127 \times \log\left(\frac{1}{0{\cdot}6}\right) = 2{,}107$ miles from the point at which it began its level flight at a height of 5,000 ft. In Fig. 6 are given curves showing the ranges for various values of q and $\eta\,\frac{L_e}{D_e}$ which have been obtained by properly evaluating the integral in equation (9), and it will be seen that the range in the above case is 2120 miles.

Fig. 6 also shows curves giving the variation of the standard brake horse-power, and the speed of the machine in terms of their values at the starting point. It will be observed that both the brake horse-power and speed fall off very slowly as the air mileage increases, and that, therefore, the value of ρ may be taken as constant throughout.

The small chart at the bottom right-hand corner of Fig. 6 enables the initial speed in miles per hour to be read off when the lift coefficient of the machine is known for its assumed condition of flight. The value of L_e corresponding with the assumed value of $\eta\,\frac{L_e}{D_e}$ can be obtained at once for the machine by the relation $V\sqrt{\frac{\rho}{w}} = \frac{14}{\sqrt{L_e}}$, (V being speed in miles per hour), the value of $V\sqrt{\frac{\rho}{w}}$ being found on the reduced speed chart for the machine similar to Fig. I, at the point where the $\eta\,\frac{L_e}{D_e}$ line cuts the curve connecting $V\sqrt{\frac{\rho}{w}}$ and $E\,f(\rho)\sqrt{\frac{\rho}{w}}$.

Numerous reductions of trials of modern aeroplanes have been made on the lines of Fig. 1, and it has been found that maximum values of $\eta\,\frac{L_e}{D_e}$ for the best machines generally lie between 6·0 and 7·0. It is probable that the maximum value of $\eta\,\frac{L_e}{D_e}$ may be as high as 7·5 or 8·0 if (1) the air-screw is designed so that it has a high maximum efficiency at a forward speed which corresponds with the maximum $\frac{L_e}{D_e}$ of the machine; (2) the axis of the machine is horizontal when the wings have an angle of attack corresponding with the maximum $\frac{L_e}{D_e}$, and (3) the head resistance is reduced to a minimum by careful design. If the latter figure is obtained by good design it will be seen that a machine having 40 per cent. of its initial total weight in petrol would be able to travel about 2,800 miles, at which distance it would have reached a height of 17,500 ft. It will be obvious from this that its rate of climb during the journey is so small that the error involved in treating its flight as level is negligible, and that whatever error there is is small enough to be about counter-balanced by the fact that the reduction in weight by oil consumption (which has been neglected in this treatment of the problem) will cause the miles per pound of petrol to be slightly greater than calculated.

In order that the time spent on a long flight may not be too great, the shape of wing section and general design of machine should be such that the maximum value of $\eta\,\frac{L_e}{D_e}$ is associated with a comparatively low value of the lift coefficient, but in order that the machine may get off at low speeds the wing section must have a high maximum lift co-efficient.

Example to Show the Numerical Relation between the Quantities in a Given Case.

Assumptions: Initial weight of aeroplane, 20,000 lbs.

$$\eta\,\frac{L_e}{D_e} = 6.$$

Initial loading 9 lbs. per sq. foot.

Lift coefficient $\left(\text{at maximum } \eta\,\frac{L_e}{D_e}\right) = 0{\cdot}35$.

Level flight to begin at 5,000 ft. where $\sqrt{\rho} = 0{\cdot}935$ and $f(\rho) = 0{\cdot}85$.

Then since

$$V\sqrt{\frac{\rho}{w}} = \frac{14}{\sqrt{L_e}}$$

$V = 76$ miles per hour,

and since

$$V = E\,f(\rho) \times \eta\,\frac{L_e}{D_e} \times 0{\cdot}375,$$

we have $E = \frac{76}{0{\cdot}85 \times 6 \times 0{\cdot}375} = 39{\cdot}8$ standard horse-power per 1,000 lbs. and pounds per standard horse-power = 25.

The machine must therefore be provided with engines having at least $39{\cdot}8 \times 20 = 796$ brake horse-power between them.

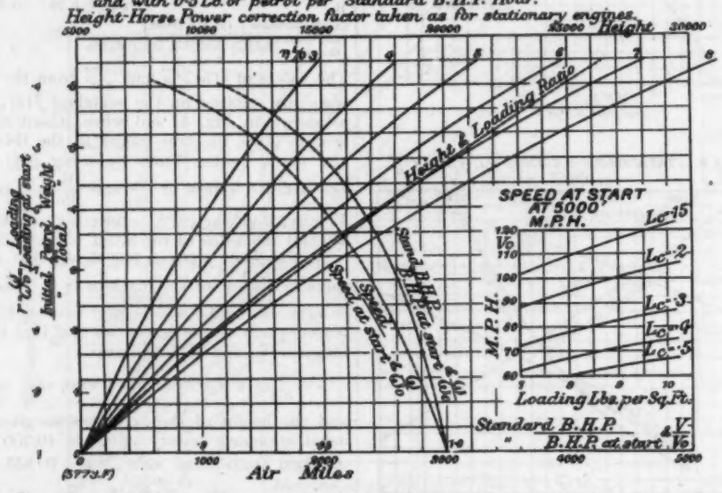
Supposing that it is required to have a range of 2,000 miles after reaching a height of 5,000 ft. during its climb, then the curve corresponding with $\eta\,\frac{L_e}{D_e} = 6$ in Fig. 6 shows that the ratio of petrol weight at the start at 5,000 ft. to the total weight must be 0·38. That is to say, the machine must have tankage for 7,600 lb., or 1,040 galls., of petrol. The height reached after 2,000 miles will be 16,800 ft., and the speed there will be $76 \times {\cdot}953 = 72{\cdot}3$ m.p.h. The mean speed = 74·2 m.p.h.

The approximate duration of flight $= \frac{2{,}000}{74.2} =$ 27 hours.

The standard horse-power at 2,000 miles $= {\cdot}969 \times 796 = 770$ b.h.p.

(To be continued.)

Fig. 6. AIR MILEAGE OF AEROPLANES. With Level Flight at constant $\eta\,\frac{L_e}{D_e}$ starting at 5000′ and with 0·5 Lb. of petrol per Standard B.H.P. Hour.



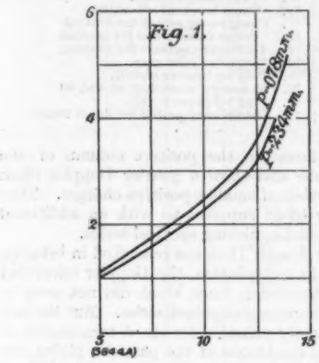
SPECTRUM ANALYSIS AND ATOMIC STRUCTURE.

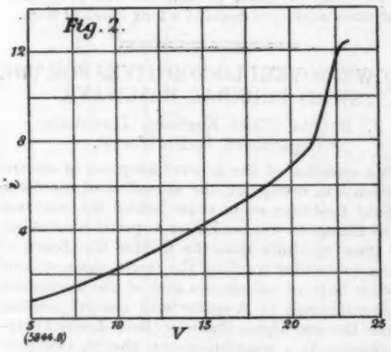
ON Saturday, April 12, Sir J. J. Thomson, O.M., P.R.S., concluded his course of six lectures on "Spectrum Analysis and its Application to Atomic Structure." Our readers may be aware that a few weeks ago Sir Joseph resigned his appointment as Cavendish Professor of Physics in Cambridge, in order to gain more time for private research. He will continue to lecture at Cambridge, however, and it is to be hoped that he will not discontinue his Royal Institution lectures either. Those lectures—surveys of the actual state of some domain of science, expressed in the clear language and explained with the aid of the simple analogues that only the master of his subject can adopt—mean much to a large circle.

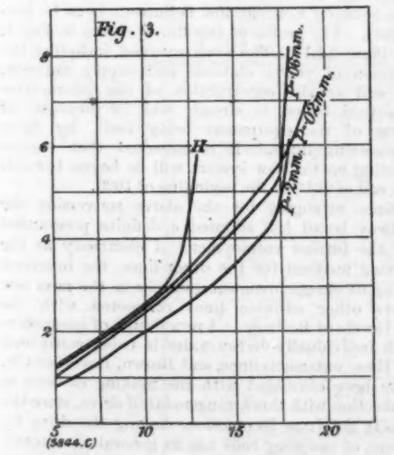
Reverting to the excitation of luminosity by the removal of an electron from the atom of the substance (a gas), and the determination of the amount of work required for this purpose, Sir Joseph pointed out that if the electron were removed right out of the atom, it would itself contribute to the electric conductivity of the gas, which should hence show an increased conductivity. He exemplified this by the aid of a few slides, illustrating the relation between the potential applied (abscissa) and the resulting current (ordinate). The experiments were made with the help of the valves, mentioned in the preceding lecture, in which electrons were shot into the gas of a discharge tube from a tungsten wire kathode independently heated by a battery current In the experiment to which Fig. 1 relates, the gas dealt with was argon at pressures of 0·078 mm. of mercury (the upper curve) and of 0·234 mm. (the lower curve). If gases behaved like ordinary conductors the current-potential curves should be straight lines passing through the origin in accordance with Ohm's law. The ionisation curves exhibited did not pass through the origin, but they kept almost straight up to points corresponding to potentials of about 12 volts; then the ionisation or conductivity increased at a more rapid rate as the potential was further raised. That indicated that electrons were detached from the argon atoms when the work done upon the atoms corresponded to 12 volts. In Fig. 2 the gas was helium at a pressure of 0·38 mm.; the curve was of the same character as the argon curve, but it kept straight over a greater range before showing a rapid increase in ionisation at about 21 volts. The work required to ionise helium would hence be nearly twice as large as the work to be done on argon. Fig. 3, represents the ionisation curves of hydrogen and of nitrogen, the latter at three different pressures

0·02 mm., 0·06 mm. and 0·2 mm. of mercury. Again the curves were first straight; in the case of hydrogen the rapid increase set in near 11 volts, in the case of nitrogen at something like 16 volts, These various gases were thus characterised by notable differences in the work required for their ionisation.

These quantitative determinations had a very important bearing upon the explanation of various peculiar effects which had long aroused considerable interest. Spectrum analysis supplied us with analytical aids of extraordinary delicacy, but it failed sometimes. We might have many substances present in a gas or vapour and yet not detect them by spectrum analyses. Ramsay and N. Collie had mixed helium and hydrogen and passed the discharge





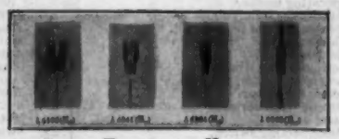


through the mixture; although the helium made up more than 30 per cent. of the gas, their spectrum was purely that of hydrogen, and not a trace of a helium line could be detected. We could understand that if a definite amount of energy had to be available to call forth the ionisation of a particular gas. The experimental conditions might be such that there would be more energy supplied than was necessary for the ionisation of hydrogen, yet not enough to call forth the ionisation of helium; in that case we should not expect to see any but hydrogen lines, and these might be intense because practically all the hydrogen was rendered luminous. The striated discharge was another exemplification of this kind; the long cylindrical tube used by Sir Joseph for demonstration was more than an inch wide and was fitted with a rod electrode at one end and a ring electrode (both aluminium wires) at the other. In such tubes, Sir Joseph explained, the luminosity was concentrated in patches which were separated by darker spaces, and it had been shown by measurements that the electric force in the tubes varied periodically; it would be negative on the convex cathode side of a striation, become positive further inward and drop to a negative value again.* With that force the energy of the electrons would vary, and we could understand that the gas would become luminous in some spots, whilst in others the energy would be insufficient for exciting luminosity. An interesting observation had been made by Crookes in connection with the striations in a hydrogen tube. The tube was connected to a mercury pump, and contained presumably mercury vapour. Examining the striations spectroscopically, Crookes observed complex spectra of curved lines, there being a bright hydrogen line in front (on the cathode side) and a blue mercury line in the rear. Now we had seen that the ionisation of hydrogen required more energy than that of mercury vapour, and we should look for the hydrogen luminosity in the stronger portion of the electric field.

The energy relations, Sir Joseph continued, also explained the differences noticed in the spectra produced by aid of the arc or spark and other electric discharges. The energy in a spark discharge was generally greater and more concentrated than in an arc discharge; the spark hence called forth lines which were beyond the energy capacity of other discharges. It was further well known that the introduction of self-induction into a circuit softened the discharge. Schuster had by these means succeeded in cutting out the air-lines, due to the presence of oxygen and nitrogen in his experiments with metallic vapour. The lines of metallic vapours required in general less energy for their excitation than the gas lines; a circuit comprising considerable self-induction might hence be insufficient for the excitation of the air lines which were thus suppressed. Of the metals caesium seemed to require the least energy, 3·9 volts, for its excitation. As regards this excitation an interesting general controversy was raised, about twenty years ago, by Pringsheim, who suggested that the ordinary spectrum production was not a question of temperature, but of chemical action. The question had been much contested from both sides. Sir Joseph considered it from the energy point of view. The average energy in the molecule or gas system in equilibrium corresponded, at ordinary temperature, say 300 deg. C. absolute, to about $\frac{1}{30}$ volt; that energy was proportional to the absolute temperature, and at 3,000 deg. C. absolute the energy should be approximately 10 times larger and should correspond to $\frac{1}{3}$ volt. Now in the case of caesium we wanted 3·9 volts, and that so far seemed to be the possible minimum. The figure 3·9 happened roughly again to be 10 times greater than the average energy value. To account for this high value we had to remember that the $\frac{1}{3}$ represented an average, and that at individual spots the energy might be considerably greater, since some particles would possess large amounts of energy and others small amounts; the luminosity might be due to a relatively small number of atoms. The ionising potentials themselves were again connected in a simple way with Planck's energy quantum and were proportional to the frequency of the radiation produced; more energy was needed for exciting violet light than for red light.

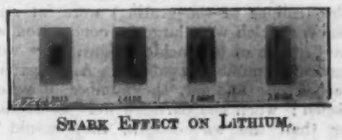
There was, further, in addition to the higher ionisation limit a lower limit, a resonance limit, which seemed to vary with the intensity of the current and not only with the potential. This luminosity was not so extensive as the luminosity due to the higher limit. When we raised the current intensity, we could accumulate energy; the energy might be taken up by one electron or by a succession of electrons, and the energy of the single electron might be lowered without sacrificing the effect.

Sir Joseph then passed to another point, the electric analogue of the magnetic Zeeman effect. Placing the spectra in very intense electric fields, J. Stark succeeded some years ago in splitting up certain lines similarly to Zeeman's magnetic resolution, but different in character. Fig. 4 shows the effects observed by Stark with fields of 28,500 volts per millimetre in the spectra of hydrogen, helium and lithium; there were resolutions into various numbers of lines. The red a line of hydrogen yielded three lines; the β line was broken up into four components, and the γ and δ lines assumed a still more complex character. In one of the helium



STARK EFFECT ON HYDROGEN.

STARK EFFECT ON HELIUM.



STARK EFFECT ON LITHIUM.

FIG. 4.

lines two sets of four components would be distinguished; one of the helium lines remained unaffected, and that held also for one of the lithium lines. These Stark effects were not so universal as the Zeeman effects; some lines, as shown, did not undergo any change, and in general the somewhat fuzzy lines of the "diffuse" series were most affected by strong electric fields.

The consideration of these magnetic and electric effects, Professor Thomson proceeded, suggested some further arguments. We assumed the atoms to be the centres of alternating fields, electric as well as magnetic. In a rarefied gas these centres would be fairly independent of one another. But imagine the gas pressure to be increased and the atoms to be found close together. The lines so far sharp, because due to individual separate systems, would broaden out because the fields of different atoms would interfere with one another sufficiently, anyhow slightly to alter the frequencies. The electric conditions on a discharge tube, moreover, were not uniform, but varied from spot to spot. Thus the lines might broaden more and more into bands, the bands would finally overlap, and the spectrum would become continuous. It was interesting to trace the continuity of the spectrum from the case of the rarefied gas, where each atom acted independently, through the liquid to the solid, in which no atom was quite independent of its neighbours. He would begin with a gas at low pressure and would not speak of spectra in the first instance. Such a gas, as well as a cloud of minute particles, would scatter any light falling upon it in all directions, though not to the same extent in all directions, but as much in front as behind. When the particles approached one another more and more, the appearance finally changed into a propagation of the light through the cloud in a definite direction without any definite scattering. How did this change from discontinuity into continuity come about? Supposing we had the particles regularly arranged at the corners of the cubes of a cubical space lattice which, in plan, would be represented by the intersections of the lines of square paper. Light falling upon such a system would set the particles vibrating; each particle would act as a centre of light, and the light rays from neighbouring particles would in general interfere with one another,

* Sir Joseph had given a fuller explanation on a previous occasion. See ENGINEERING, June 8, 1917, page 550.

CONNECTIONS OF ELECTRIC LOCOMOTIVE FOR SWISS FEDERAL RAILWAYS (*see* FIG. 8 *on opposite page*).

1. Pantograph current collector.
2. Disconnecting link.
3. Choking coil.
4. Main oil switch.
4A. Remote control release coil.
4B. Operating motor.
4C. Contact for signal lamps.
4D. Hand release.
5. Maximum current relay for switch 4.
5A. No-voltage relay for switch 4.
6. Plug for signal lamp.
7. Current transformer for main circuit.
8. Main transformer.
8A. Change-over connections for 15,000 volts to 7,500 volts.
9. Tapping switch.
9A. Spark drawing device.
10. Oil switch for main motors.
10A. Maximum current relay.
10B. Operating motor.
10C. Contact for signal lamps.
10D. Remote control release coil.
11. Main motors.
11A. Field winding.
11B. Compensating winding.
12. Reversing switch.
12A. Operating motor.
13. Current transformers for ammeters 47 and 48.
14. Disconnecting switch.
15. Slip ring for earth connection.
16. Operating gear for control apparatus.
16A. Control motor.
16B. Field winding for forwards.
16C. Field winding for reverse.
16D. Parallel resistance for armature of motor a
16E. Slip coupling, interlocking disc and pawl
16F. Interlocking magnet.
16G. Return signal apparatus.
17. Relays for the control motor.
17A. For forwards.
17B. For reverse.
18. Relay for switching in interlocking magnet.
19. Switch for operating gear 16.
20. Master controller.
20A. Main drum.
20B. Reversing drum.
20C. Reversing handle (fixed in place).
20D. Controller handle (removable, one per locomotive).
21. Switch for auxiliary circuit.
22. Plug for 30 cables.
23. Motor-driven compressor.
24. Automatic pressure governor.
25. Single-pole change-over switch from the compressor sets.
26. Motor-driven oil circulating pump.
27. Switch for oil pump set.
28. Motor-driven fans for main motors.
29. Switch for fan motors.
30. Motor generator.
30A. Single-phase induction motor.
30B. Automatic pressure regulator.
30C. Ohmic starting resistance.
30D. Inductive starting resistance.
30E. Direct-current generator.
31. Storage battery.
32. Switch for remote control release of main switch 4.
33. Switch for remote control of oil switches 10.
34. Switch for machine room lighting.
35. Switch for head lights.
36. Head lights.
37. Plug for portable lamps.
38. Switch for instrument lamps.
39. Lamp for machine room.
40. Lamp for instruments.
41. Signal lamp indicating when oil switch is open.
42. Wall-type switch.
43. Switch for cab heating.
44. Heaters for cab.
45. Main ammeter.
46. Voltmeter for overhead pressure.
47. Ammeter for main motors 1 and 2.
48. Ammeter for main motors 3 and 4.
49. Ammeter for braking current of motors 1 and 2.
50. Ammeter for braking current of motors 3 and 4.
51. Operating gear for braking controller 52.
52. Braking controller.
53. Braking resistance.
54. Fuses.
55. Operating valve for the current collectors.
56. Three-way cock.
56A. Interlocking handle for high-tension room.
57. Shut-off cock.
58. Main switch for auxiliary circuit.
59. Ammeter for direct-current generator 30E.
60. Voltmeter for direct-current generator 30E.
61. Switch for the single-phase induction motor 30A.
62. Interlocking contacts.
63. Foot-warmer.
64. Earth switch.
65. Plug for wattmeter.
66. Switch for bridging over 65.
67. Double choking coil.
68. Switch for current to commutating field of main motors.
69. Interlocking contact.
70. Circuit-breaker for heating.
71. Change-over switch for heating.
72. Current transformer for heating.
73. Voltmeter-ammeter for heating.
74. Voltmeter resistance.
75. Plug for heating circuit.
76. Shunts for ammeters 49 and 50.
77. Plug for depot feeder.
78. Change-over switch for depot feeder.

as in the case of a grating. The plane grating of one dimension consisted of a series of parallel rulings, say vertical lines drawn in the plane of this paper. A beam of light passing normally through this paper, from front to back, would produce a series of interference patches of bright and dark spots, arranged along a horizontal line on both sides of the spot on which the light fell. If the particles (rulings of the grating) were far apart, at distances which were large by comparison with the wave-length of the incident light, there would be an enormous number of patches. As the particles approached one another, the number of patches diminished; when the particles were at distances smaller than the wave-length, they would all disappear, except that there would be strong interference in one direction, which was the direction of the propagation of the light. For in such a case, if the light were supposed to travel in the horizontal direction, successive particles in the same horizontal row would be reached the one after the other, yet they would all vibrate in phase; the resulting amplitude of vibration would be the sum of the single amplitudes and the aggregate energy, being proportional to the square of the amplitude, would be proportional to the square of the number of particles. In all other directions the aggregate energy would merely be proportional to the number of particles. Hence there would be a decided predominance in one direction, and in this way we could imagine to pass from the scattering produced by a fog to the propagation of light by a transparent drop of water.*

The spectra which he had so far considered, Sir Joseph then said, might be resolved into series of lines representing definite numerical groupings. The majority of spectra lines did not display any series, however, and we knew little about series especially in the ultraviolet and in the regions of very small wave-lengths, the regions of the Schumann rays, which extended down to 900 Angström units, and of still shorter wave-lengths. The experimental exploration of these regions had to overcome exceptional difficulties. The Schumann rays were stopped by 1 mm. of air; hydrogen was, however, transparent to Schumann rays; of solids practically the white fluospar was alone available for making windows for these rays. That there were rays even shorter than the Schumann could be demonstrated by the peculiar glow which they called forth on the glass of discharge tubes containing air at a particular low pressure. An ordinary discharge bulb was used for the demonstration; the air in the bulb did not display any luminosity, but the glass walls shone in a striking, though faint olive-green phosphorescence, which was quite distinct from the yellow-green glow to which the cathode rays gave rise when impinging on glass; the real effect produced was not in the visible spectrum, but far away in the ultraviolet. Sir Joseph also demonstrated another effect of radiations of very small wave-lengths. In this case a lateral tube branched off from the cylindrical discharge bulb, and into the far end of this tube a short length of copper wire was fused, the wire was connected to an electroscope. Between the discharge bulb and the inner end of the wire the lateral tube was encircled by the pole-pieces of an electromagnet; this electromagnet was added in order to stop any ordinary cathode rays generated in the bulb by the discharge. When the discharge passed, the electroscope—previously charged up so that its gold leaves diverged—collapsed, and the turning on or off of the electromagnet made no difference. Thus the gas in the bulb had been ionised and rendered conductive, but not by ordinary cathode rays, and it could be shown that the effect was produced only by a peculiar kind of negative glow, due to slow cathode rays, which were very easily absorbed like the Schumann rays, but of still smaller wave-length, belonging to the hardly-explored region between Schumann rays and Röntgen rays. That this was so Sir Joseph had proved with the aid of the special bulb, which he had described a few years ago; the electrode system of this bulb could be shifted within the bulb, enabling the experimenter to study particular regions of the bulb. Sir Joseph had discoursed on his study of those slow cathode rays just before the war, but had not been able yet to resume [see ENGINEERING, April 2, 1915, page 384].

Professor Thomson finally turned to the important information that a new powerful method of searching for series in spectra had placed at our disposal. That method, upon which he had not touched so far, was Stark's application of the Doppler principle to discharge phenomena. Sir Joseph first gave a demonstration of the fundamental experiment, the production of positive rays, consisting of charged hydrogen atoms, in a hydrogen discharge tube fitted with a perforated cathode. Those particles moved at velocities which might reach one three-hundredth of the velocity of light; such a movement should be sufficiently fast to give rise to an appreciable Doppler effect. Owing to the Doppler effect the frequency of a radiation would apparently increase if the source of the radiation were approaching the observer, and the spectrum lines should therefore be displaced towards the violet in that case, whilst they would be displaced towards the red if the source of light were receding. With particles travelling at one three-hundredth the velocity of light the change in frequency should, indeed, amount to one-third of its value, which was an enormous figure for spectroscopic measurements. By measuring the displacement of the lines we could conversely determine the speed of the particles. Observing the Doppler effect in various gases and vapour, Stark found that sometimes all the lines of an element were equally displaced, whilst in other cases, notably in those of mercury and helium, some lines were distinctly displaced much more than others. Those lines could only be ascribed to different carriers. Now Sir Joseph had proved by his positive ray analysis that atoms of different elements might lose one or several electrons, up to seven electrons, in fact, in the instance of mercury. The more electrons were detached, the bigger the electro-positive charge of the residual atom would be, and the highly-charged particles should, therefore, move faster in the positive column of the discharge tube and show a greater Doppler effect than the carriers of smaller positive charges. Thus the Doppler effect supplied us with an additional criterion for distinguishing spectral series.

So far, Sir Joseph Thomson remarked in bringing his lectures to a conclusion, the Doppler effect had only been observed in lines which did not seem to belong to otherwise recognised series. But the test was undoubtedly valuable for the determination of the electrical conditions of the particles giving rise to the different lines, though the study of those conditions might yet demand a long space of time.

* Compare Sir Joseph Thomson on "Problems in Atomic Structure," ENGINEERING, February 22, 1918, p. 208.

BROWN-BOVERI LOCOMOTIVES FOR THE SWISS FEDERAL RAILWAYS.

By J. BUCHLI (Chief Engineer, Locomotive Department, Baden Works).

THE question of the general adoption of electric traction was occupying the attention of the Swiss Federal Railways some years before the outbreak of the European war, and after a special commission had gone carefully into the matter the Board of Directors decided to adopt the single-phase system, in view both of calculation and of the favourable results obtained in practice with electric traction on the Bernese Alpine Railway (Bern–Loetschberg–Simplon). As a commencement, the St. Gotthard line between Erstfeld and Bellinzona is to be converted. The profile of this line is shown in Fig. 1, on Plate XLII. The work involved, including the erection of power stations and supply network, as well as the construction of the locomotives described below, is already well in progress, all parts of the equipment being built by Swiss engineering firms. It is expected that regular running on the new system will be begun towards the end of 1919 or the beginning of 1920.

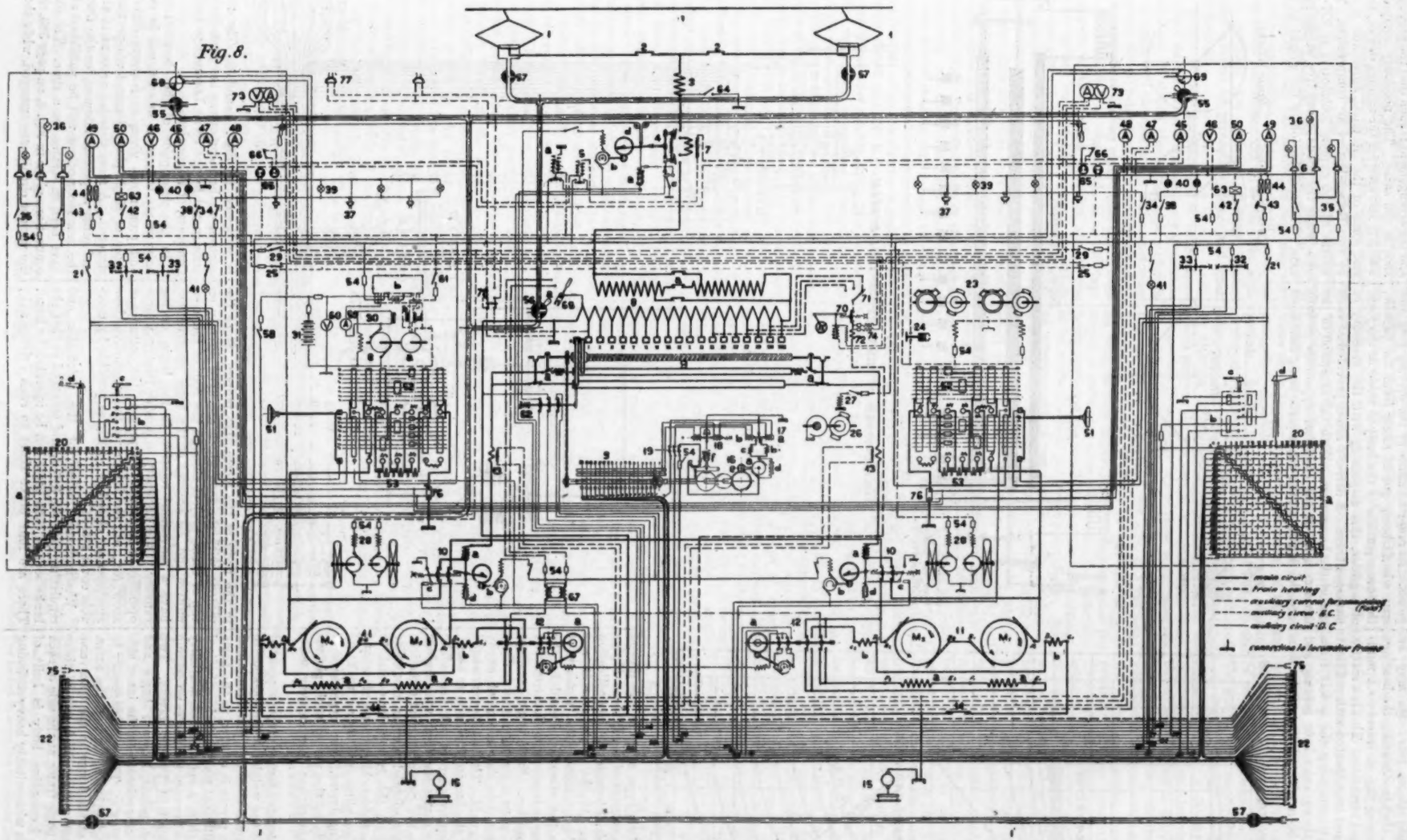
Since arranging for the above conversion the railway board has adopted a definite programme for the further employment of electricity as the driving medium for the other lines, the intention being to change over successively in the next few years other suitable lines connected with the St. Gotthard Railway. A new design of locomotive with individually-driven axles is being considered for these extension lines, and Brown, Boveri et Cie. have been entrusted with the making of tests in connection with this arrangement of drive, since the results got from locomotives having the drive by means of coupling rods has in general not proved entirely satisfactory. These tests can the more easily be carried out as a locomotive built by the firm named for testing purposes is already available.

Up to the present 24 heavy goods and express locomotives have been ordered for the St. Gotthard line, half of these being placed with Brown, Boveri et Cie. It was intended to deliver the new locomotives in groups, the completion of the first lot—consisting of four trial locomotives of different types—being carried out as quickly as possible so that they might be experimented with on the Bernese Alpine Railway and the results taken into account in the construction of the subsequent locomotives.

DIAGRAM OF CONNECTIONS OF ELECTRIC LOCOMOTIVE FOR SWISS FEDERAL RAILWAYS.

(*For References, see opposite Page.*)

Fig. 8.

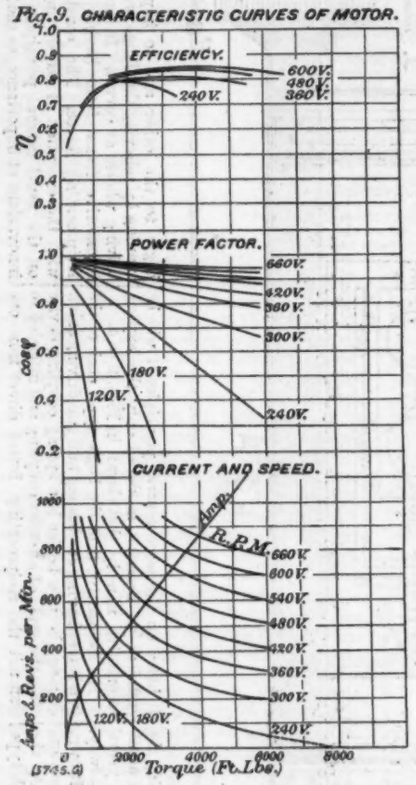


Unfortunately, it was found impossible to adhere to this programme owing to the war, and, in view of the difficulties of obtaining raw materials and the continued drop in the coal imports, the Federal Railways have decided to push on with the completion of the other 20 locomotives without awaiting the results of the trial locomotives, so as not to prolong unduly the inauguration of electrical working on the St. Gotthard line. In designing the locomotives full advantage was taken of the available data concerning the results of several years' running experience on the Bernese Alpine Railway. The two types of locomotive put forward by Brown, Boveri et Cie., and at present in course of erection, are shown in Figs. 2 to 7, on Plate XLII. As the mechanical and electrical construction of each type is based on the same general principles it will be sufficient to describe in detail only the express locomotive, namely, that shown in Figs. 2 to 4.

The locomotive is of the bogie type, each of the two bogies having one leading and two driving axles. Joining the two bogies is a spring coupling device after the style of a tender coupling and intended to transmit the reciprocating forces direct from one bogie to the other and so improve the general running by relieving the flange pressure of the inner driving wheels at curves. It further prevents the locomotive frame from having to take up the reciprocating forces. The constructional details, with the exception of the driving gear, are based on the usual general principles, and contain no innovations of importance, so that it is unnecessary

to enter further into them here. It may be mentioned, however, that in designing the bearings the question of reducing the oil losses to a minimum was given special attention. This is a matter which, as a rule, has not been treated with sufficient consideration. For transmitting the power from the motor to the driving axles spur gearing and coupling rods have been adopted, as will be seen

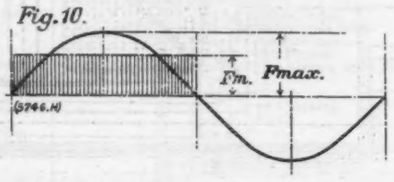
Fig. 9. CHARACTERISTIC CURVES OF MOTOR.



from the figures. This type of drive has proved successful on the locomotives of the Bernese Alpine Railway, once the initial troubles in the application had been overcome. At the same time it was considered advisable to reduce the number of coupled axles, since the vibration caused by the coupling rods increases in intensity with the number of axles coupled together. Each bogie possesses two motors geared on to a common intermediate shaft which is connected to the driving wheels by means of the coupling rods. The latter are arranged one on each side of the locomotive and, as usual, with a relative displacement of 90 deg. The pinions on the motor shafts are fitted with springs to give flexibility in the circumferential direction, this arrangement being adopted in order to equalise the tooth pressures on the two pinions, and to compensate for the sudden alterations of torque chiefly due to the coupling rod drive with its changing reciprocating forces. The experience of Brown, Boveri et Cie in the use of such pinions with single-phase motors has been entirely satisfactory.

Two strongly-constructed centre pivots supported from the bogies take the weight of the locomotive body, together with the electrical plant contained therein. One of the pivots is centred in the bogie while the other has sufficient play in the longitudinal direction to ensure that in spite of the flexibility of the coupling device between the bogies no driving forces can be transmitted by the pivots. Two auxiliary supporting points between bogie and frame are arranged immediately to the inner side of the inmost driving axle. These are necessary to obtain an equal distribution of load on the axles. To obtain stability of the frame in the transverse direction light springs are provided, two of these being placed on the bogie frame at the side of each centre pivot. The locomotive body is built of substantial sheet iron with suitably heavy stiffening pieces. In order to allow of the driving gear and spur wheels being got at easily from the outside, the lower portion of the body is made in the form of a girder, this dispensing with the necessity of having a truss. A driver's cab is provided at each end of the locomotive. With the exception of the motors, none of the electrical apparatus is built into the bogies, all the other parts being contained

Fig. 10.



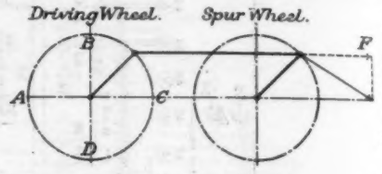


Fig 11

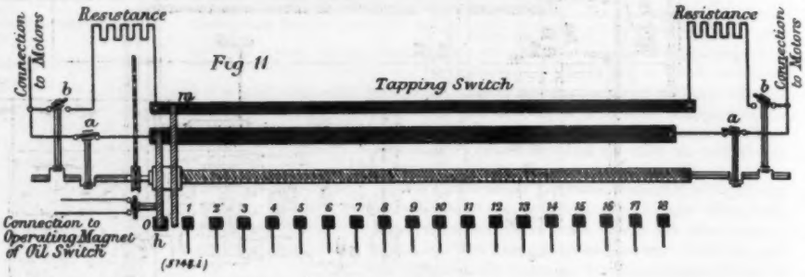
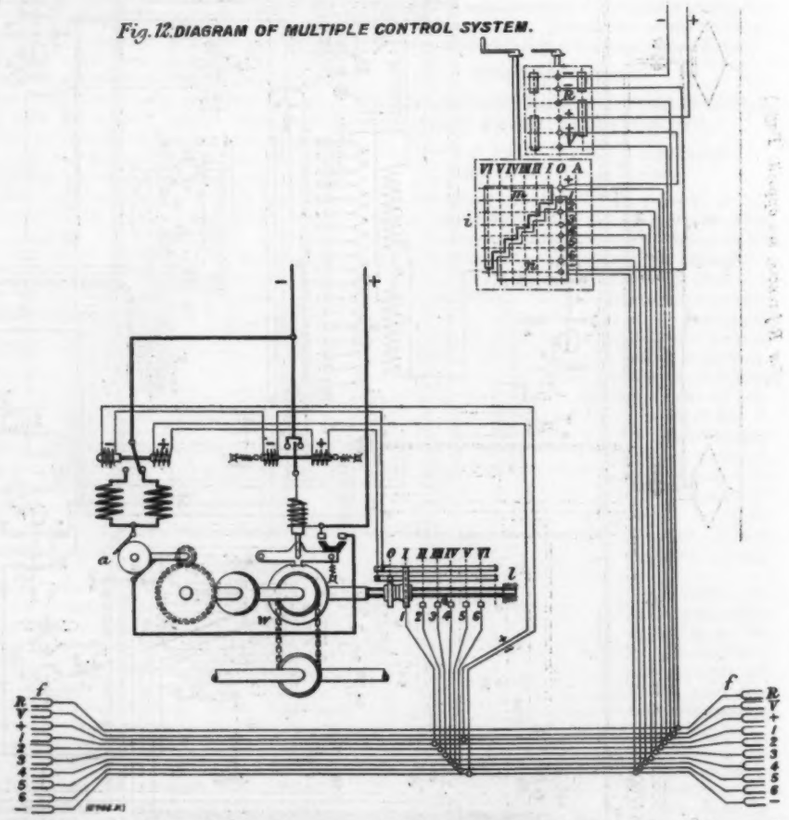

Resistance
Resistance
Connection to Motors
Connection to Motors
Tapping Switch
Connection to Operating Magnet of Oil Switch
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Fig. 12. DIAGRAM OF MULTIPLE CONTROL SYSTEM.



and the arrangement is such that the pressure of each shoe is the same. The necessary compressed air, which is also used for the sanding device, the whistle and some of the electrical apparatus, is produced by two Brown-Boveri air compressors. The total weight of the express locomotive is 107·6 metric tons, while the goods locomotive weighs 121 metric tons. The distribution of the weight on the axles in the body of the locomotive proper. Since the motors, with the fans which are fixed directly on top of them, project through the floor of the locomotive and, on account of the bogie construction, have a movement relative to the bogie during running, it was necessary to provide relatively large openings in the floor. To prevent the entrance of snow, &c., into the interior of the locomotive these apertures are closed as tightly as possible by movable cover plates.

Westinghouse brakes of the automatic and regulating type are fitted, and arranged so that the brake rods of each bogie can be operated by hand. There are four brake shoes to each driving axle, is indicated in Figs. 2 and 6. The mechanical portion of the locomotives has been designed and constructed by the Swiss Locomotive and Machine Company, of Winterthur.

In the description of the electrical equipment only points of general interest will be dealt with, and prominence given to features differing from those of single-phase locomotives previously constructed. A more detailed account of the motors and other apparatus adopted for the first time on the new locomotives will be published after these have been in service for a time. The diagram of connections given in Fig. 8, on page 563, shows how the various circuits are arranged, while the position

of the different pieces of apparatus on the locomotive is shown in Figs. 2 to 4. All the control switches with their operating gear are built together with the transformer, so that the whole forms a complete unit which can be put in or taken out bodily by an opening in the roof. This arrangement, which is quite novel, has the advantages of permitting the erection and testing of such a unit independently of the locomotive, of requiring very short cable connections, taking up small space and of being easily accessible from all sides. The high-tension portions are suitably guarded against accidental contact by protecting covers and interlocking devices.

The frame of the transformer is constructed specially for the reception of the accessory apparatus. The sides are of strong sheet iron with stiffening pieces of angle and channel iron. The transformer is oil cooled, the oil being sent by a circulating pump through a system of cooling pipes fitted to the sides of the locomotive. As the result of a thorough investigation of the cooling question and of the experience gained under actual running conditions during many years the firm has decided to instal oil-cooled transformers where a high overhead line voltage is adopted, in place of the more usual air-cooled type. The former is only slightly heavier for the same output with the cooling arrangement mentioned, while it is decidedly more reliable than the air-cooled type. In consequence of this greater reliability only one transformer has been installed in the case we are dealing with instead of dividing the output over two transformers in order to provide a partial reserve. The transformer is designed for a continuous output of 1,750 k.v.a., the high-tension side being wound for 15,000 volts, but adaptable for 7,500 volts; the secondary pressure is 1,325 volts at no load, and the frequency 16⅔ cycles per second. The core is arranged in a horizontal position, the section of the limbs being rectangular; the high-tension winding is to the inside. The windings are specially fixed with end plates and at the sides with cast steel clamps to guard against movement or deformation due to short-circuit forces. The arrangement of the windings is such that the circulating oil cools both sides of the rectangular wire used, being directed by baffles. The weight of a complete transformer with pump and separate cooler is 12·4 tons, the dimensions being: Length, 7 ft. 1 in.; breadth, 4 ft. 11 in.; height, 5 ft. 2 in. to the cover. The transformer is designed for a temperature rise of 99 deg. F., on continuous rating, measured by the resistance method. As insulation test 45,000 volts is applied between high and low-tension windings during 30 seconds 10 times with 5-minute intervals.

The current is collected from the overhead line by means of two independent pantograph collectors. The current passes from the collectors through safety devices fitted on the roof, for protection against lightning and excessive voltage rises, to the high-tension switch of the transformer, through the primary winding of the latter and hence to the locomotive frame, and finally to the rails. The transformer switch is arranged in the roof so that separate leading-in insulators are dispensed with. Special mention may be made of the fact that the switch has two switching-in contacts which are connected through a resistance. This is shown in the diagram Fig. 8.

The two motors of each pair are connected in series while the two pairs are in parallel with one another. The series arrangement is allowable as the mechanical coupling of the two motors ensures an equal distribution of the voltage. The series connection was preferred on account of the saving in copper for the connecting cables, as well as in weight and space, due to the current being only half of that with parallel connection. The motors are specially well ventilated, the air being drawn in from the interior of the locomotive and blown out to the atmosphere underneath. The motors are of the single-phase series type, with compensating winding and commutating field with phase displacement. With a current of 900 amperes they develop continuously a torque of 4,200 lb.-ft. The tension at the terminals works out at 515 volts at a speed of 640 r.p.m. The speed may be raised to 960 r.p.m. with a torque of 1,660 lb.-ft., the current and terminal voltage being 450 amperes and 540 volts. There are 12 brush holders to each commutator, with a total of 24 brushes each 2½ in. broad and ¾ in. thick, which are similar dimensions to those usually adopted for direct-current motors. Between the armature conductors and the commutator there are resistance connections. These are pressed by wedges against the material used for insulating them so as to get a good conduction of the heat generated especially during the heavy starting periods. In Figs. 9 and 10, on page 564, all the principal characteristics of the motor are indicated. The speed and output of the motors are regulated by altering the voltage supplied to the latter, for which purpose the low tension winding of the transformer has 19 tappings, one of these being, however, connected to an earthing terminal. Altogether the tension can be varied from 237 volts to 1,325 volts, making an average of about 70 volts per step, or 35 volts on each motor. The voltage increase per step is of course not always the same, the variations being smaller at the middle than at the end tappings, as far as the design of the transformer allows. Such an arrangement of tappings is chosen so that on reaching the limit of adhesion between wheel and rail at starting a finer regulation in the tractive effort can be made. The leads are brought out through the transformer cover direct to the tapping switch. This latter apparatus differs considerably from the type usually adopted for similar purposes. It consists of two cell-type switches, as used in conjunction with storage batteries, but combined in a novel manner to form a single unit. Each of the two sides of the apparatus is divided up to suit the set of motors to which it is connected. The leads from each pair of contacts go together to their corresponding transformer tapping. Fig. 11, on page 564, which, however, for simplicity's sake, does not indicate the double-sided arrangement of contacts, shows diagrammatically the connections of the tapping switch. Two groups of brushes *h* and *m*, insulated from each other, connect alternatively the various transformer steps to the motor through the contact bars and the spark drawing devices *a* and *b*. Brush *h*, which is only in circuit when moving from one step to the next, connects a resistance temporarily between *h* and *m*, thus preventing any break in the circuit or the short-circuiting of individual transformer steps. The sequence of making and breaking contact with brushes *h* and *m*, as well as at the spark drawers *a* and *b*, takes place positively and in such a way that the brushes always make and break contact when carrying no current, sparking at the brushes being thus not possible. The only place where sparking takes place is at the spark drawers, which are provided with blow-outs and are easily accessible. Such a construction shows decided advantages as regards operation and upkeep in comparison with other designs where all the steps are provided with spark drawers. Further, as compared with the well-known contactor control there is the advantage of absolute positive operation of the switching process, thus avoiding a separate interlocking arrangement between the various steps. The apparatus has been completely tested by Brown, Boverie et Cie. during many years under running conditions.

The tapping switch, as well as the other control apparatus, is operated by direct-current motors. A small motor generator in conjunction with a storage battery supplies the necessary current. It would appear at first sight that such a conversion of energy makes the installation unnecessarily complicated, but there are considerable advantages to be obtained with direct current as regards the construction of the control gear and, further, the battery allows of this gear being operated as well as provides for the lighting of the locomotive, should the main supply fail. The specification calls for the controlling of two locomotives from a single locomotive cab, which means multiple control. The principle of the system, due to Mr. Couwenhoven (Dr. of Eng.), which is here adopted for the first time, and which is illustrated in Fig. 12, on page 564, consists in providing the controller *i* with two sets of polarised contacts *m* and *n*, arranged in steps, and in controlling the auxiliary motor of each driving unit by polarised relays. The controller is provided with a set of fixed contacts corresponding to the number of steps, the contacts being connected to a similar number of control cables running through the train and in each locomotive with the like number of contacts of a return signal apparatus *l* which is rotated by the auxiliary motor. In each position of the controller a certain number of the control cables are connected with its positive and a like number with its negative contacts, the auxiliary motor *a* then rotates until the contacts of the return signalling apparatus are brought into the positive and negative limit positions.

A further important demand of the railway authorities was that each locomotive must be provided with an electric brake. This was not chiefly with a view to delivering energy back to the line, but rather to avoid dust being produced at the wheels of the locomotive and to lessen the wear of the tyres and brake shoes. The fine iron dust produced in large quantities during braking finds its way into the interior of the locomotive, especially when assisted by the suction of the motor fan. Here it is deposited on the windings of the apparatus and in the motors, thus giving rise to troubles and breakdowns. When one considers that on the steep gradients of the Bernese Alpine Railway, for instance, the quantity of such dust produced amounts to 40 tons per year, the requirements of the railway board are seen to be well grounded. An improved system of electric braking allowing of generating back into the line is being utilised for the first time on the test locomotive described hereafter, and it is intended to adopt such a system on the locomotives still on order. The locomotive we are now dealing with, as shown on Plate XLII, has resistance braking, that is, the energy generated by the motor in the form of direct current on down gradients is dissipated in resistances, the motor being then disconnected from the mains. These resistances are mounted on the roof of the cab and are cooled by the natural draught of the moving train. It is evident, however, that only a part of the whole braking of the train can be done by this method. As the regulation of the braking effect is well enough known in ordinary direct-current equipments, there is no need to describe further the system in question.

As regards the duty required from the locomotives the following particulars will be of interest. Both types of locomotives are to be used on the run Lucerne–Chiasso, which has a contour as shown in Fig. 1. The first portion to be converted to electric drive is the mountain section between Erstfeld and Bellinzona, as already mentioned, the electrification of the two extensions following shortly afterwards. The express locomotives, Figs. 2 to 4, must be able to haul a net load of 300 tons at a speed of 31 m.p.h. on a gradient of 2·6 per cent., while the goods locomotives, in addition to having a speed of 31 m.p.h. under the same conditions, must reach 21½ m.p.h. with a net load of 430 tons. It is further specified that both trains must be able to be started up from rest to full speed in 4 minutes on the same gradient. The overload demanded is 20 per cent. for 15 minutes at a time. The above normal full-load conditions represent an output of 2,500 h.p. (1 hour rating) per locomotive at the motor shafts, with a tractive effort of 27,500 lb. and 37,500 lb. respectively at the circumference of the driving wheels. These amounts are increased to 35,500 lb. and 48,500 lb. during starting on the up gradient.

(To be continued.)

WAR-TIME LUBRICANT FOR LOCOMOTIVES AND RAILWAY CARRIAGES.—According to a communication by Mr. Esser, of Luxemburg, published in "Glaser's Annalen," a mixture of mineral oil and tar oil has given satisfaction as lubricant for high-speed traction machinery and carriages, whilst tar oil alone is only serviceable for low speeds. It is not claimed that this mixture comes up to the quality of the best lubricants available for such purposes in peace time. The parts should not be mixed in the cold, lest heavy hydrocarbons of the anthracene type be deposited which would bind the parts. When the tar oil is mixed hot, a sediment is at once formed, but there is said to be no further trouble. For the summer service 80 parts of tar oil may be mixed with 20 parts of mineral oil; for the winter months the two constituents should be used in equal proportions, and in very cold days up to 15 per cent. of petroleum should further be added to keep the lubricant limpid.

INDUSTRIAL NOTES.

As stated in our last issue, the Coal Commission has resumed its sittings on the subject of the nationalisation of the coal mines under the chairmanship of Mr. Justice Sankey. The members are the following: *Coal-owners*, Mr. J. T. Fergie, Mr. R. W. Cooper, Mr. Evan Williams. *Miners*, Mr. R. Smillie, Mr. F. Hodges, Mr. H. Smith. *Appointed by Government*, Mr. Arthur Balfour (of Sheffield), Sir Arthur Duckham, Sir Allan Smith, and Mr. Sidney Webb, Mr. R. H. Tawney and Sir L. Chiozza Money.

The first sitting was held on Wednesday, April 23, when the first witness called was Professor Pigou, Cambridge University, who said that when an existing method of running an industry was up for trial as against a proposed new method, there was a tendency to exaggerate the advantages of a change. The following appeared to be the alternatives to the present system of working the coal industry: (*a*) Unification under a private combine subject to Government control in the matter of prices and conditions of work. (*b*) Transference of the mines, by purchase, to a special "public utility" authority on the pattern of the Port of London Authority. (*c*) Continuance of the mines in private ownership, but permanent establishment over them of Government control empowered to issue orders not only concerning prices and conditions of work, but also in regard to organisation and methods of production. (*d*) Purchase of the mines by Government and their leasing to private concerns covering suitable areas, subject to various conditions as to co-operative working and prices. (*e*) Purchase by Government of a controlling interest in all mines and appointment of Government representatives on the Board of Directors. (*f*) Government ownership with Government management through a Minister of Mines. Professor Pigou then enlarged upon the various alternatives in their order, and in regard to the last he added that under full nationalisation there were possibilities of better results than any other plan could offer; with complete control over the whole mining industry, operating through officials and workmen who felt themselves servants of the State, a perfectly wise autocrat could do wonderful things, but whether a Minister of Mines, whose political complexion had always to be that of the Government of the day, would succeed in this was a different question. The lease system, under certain considerations, seemed to him the best of the other systems.

The next witness was Sir William J. Ashley, Birmingham University, who expressed the opinion that the British coal industry before the war had not reached, by internal evolution, a situation in which the imposition of a single authority had become relatively easy. He compared the situation in Great Britain with that which ruled in Germany; in the latter country, the mining concerns were few in number and mostly large in size. The following, he added, were among the possible merits of unification as compared with nationalisation: (*a*) It avoided the necessity for valuing the property interests, together with the large financial operations involved in national purchase. (*b*) It retained in some measure the influence of the existing motives of self-interest and individual enterprise on the part of the existing owners. (*c*) It did not directly involve the Government in the difficulties and probable odium, incident to the determination of the price to be charged from time to time to the industrial users of coal. (*d*) It did not directly involve the Government in the difficulties and probable international complications incident to the regulation of the export of coal with respect to quantity, direction and price. Sir William also stated that it would be an enormous task to bring the whole of the coal production of the country under control in the interest both of economy of production and of the highest possible standards of comfort and safety for the miners. If nationalisation should be recommended, consumers should be definitely represented in the form of control set up.

At the sitting of Thursday, April 24, Professor E. Cannan, London University, stated and explained that nationalisation would not benefit the taxpayer, neither would it benefit the consumers of coal. In regard to it benefiting, or not, the miners, no one doubted, he added, that during the war persons engaged in Government service, with the exception of the Army and Navy, were in clover compared to others in all the belligerent countries. But the means to pay them were then provided by borrowing, stimulated and assisted by watering the currencies, a method which could not endure for any length of time. He came to the conclusion that if nationalisation became the order of the day, and especially if the railways are nationalised, as seemed likely, the nationalised miners were not well advised if they expected to enjoy a specially favoured position such as State employees were supposed to have enjoyed in pre-war days. In the case of nationalisation not being effected, he suggested that a definite percentage of the profits of all mines be paid into a common fund to be distributed among all the miners in proportion to the amount of wages of each miner.

Mr. Harold Cox, who followed, said the demand for nationalisation was in no way the outcome of present conditions of service in the mines; the Nationalisation of Mines and Minerals Bill was adopted by the Miners' Federation in October, 1912. The demand sprang from a theoretical preconception in favour of nationalisation as an ideal solution of social problems. The scheme of nationalisation proposed by the Fabian Society included a provision to the effect that every person employed in the mines of the State should be compelled to be a member of the Miners' Federation; this meant that the power of the federation, already almost irresistible, even by all the forces of the nation, would be further strengthened. Yet the interests of that body and of the class it represented were obviously not identical with those of the community as a whole. The examples of the post office, telegraph and telephone services showed that the State failed to make a profit where private capitalists succeeded. In view of these experiences and of the entirely speculative character of the figures given by the Fabian Society concerning the mines, no value whatever attached to the calculation that there would be a profit to the Exchequer following nationalisation. All the criticisms as to housing was irrelevant; they had nothing to do with nationalisation, for it was not the practice of the State to provide houses for its employees. The question as to the prevention of accidents was also irrelevant. The suggestion that technical improvements in working could be more rapidly adopted by the State than by private owners was contrary to all experience. Considerable stress had been laid upon the alleged waste involved in the use of privately-owned trucks for the conveyance of coal, but it was forgotten that a truck provided the cheapest form of storage for coal. Mr. Cox then reviewed various schemes which had been put forward at different times by the Fabian Society, the Miners' Federation, committees, &c., and pointed out the defects of each. He stated that the self-interest of private individuals in competing with one another worked for the advantage of the rest of the nation, whilst the self-interest of Government officials scheming to magnify their offices and to cover up one another's mistakes *worked against* the interest of the nation.

On Friday, 25th, evidence was given by Professor W. R. Scott, Glasgow University, who said that the organisation of the coal industry should be such as would provide for its progress both internally and externally. The provision of capital for improvements had also to be kept in view, as well as the type of organisation most favourable to the providing of ideas and inventions which formed the prior conditions of progress. Up to the present there had been a tendency for State employment to induce gradually and almost insensibly a species of creeping paralysis in the efforts of the workers. A factor which entered into the probable consequences of nationalisation was the effect it would have upon individual initiative and enterprise; in the coal industry, room for both these would remain and would be urgent. There would even be a greater need for improved methods of mining coal; great judgment and enterprise would be required in the export trade. Hitherto, public management had tended to be more rigid than enlightened private management, and hence, Professor Scott stated, it was repressive of initiative and enterprise. Within the sphere of public ownership, progress in invention and improvements in methods would be slower than when enterprise was free. In industry, Government had been non-creative, and where inventions had resulted in State-managed enterprises, these had been the work of men who had been trained under competitive conditions. Routine instead of enterprise seemed to be the watchword of public undertakings. Their enterprise, where this course was risked, had often been more unfortunate than their inaction. Even if a case for nationalisation had been demonstrated—which in his view had not been accomplished—practical wisdom, Professor Scott concluded, would suggest its accomplishment not suddenly but by stages.

Mr. J. A. Hobson said the nationalisation of railways was practically a certainty in the near future, and their early electrification was probable. The nationalisation of railways and of public services dependent on fuel was insecure so long as effective control of coal-mining remained in the hands of private companies. Any scheme of joint control implied a very imperfect unification, and a co-partnership of capital, labour and the public would also be unsatisfactory. The new mind of the workers, and especially of the miners, was definitely set on nationalisation. The dislike to work for companies was not only due to a feeling on the part of the men that their labour had been exploited for high profits during the war; there appeared to be a widefelt preference for a new status as employees in a public service. In nationalised coal mines, Mr. Hobson added, the men would be less likely to press excessive or unreasonably large demands on the public than on private profiteers; the greater publicity of mining conditions following nationalisation would be likely to educate a strong public opinion hostile to a privileged position for miners at the expense of the consumer or taxpayer; the growing education of the working classes and their increased consolidation for industrial and political objects would furnish the required checks upon the tendency of any single group of workers to advance much faster than their fellows, and even to injure those fellows as wage-earners, consumers or taxpayers, by excessive demands, pressed unduly at their expense.

The sittings of the Commission were resumed last Tuesday, when Mr. Sidney Webb gave evidence. He said the root cause of the relative inefficiency of the British coal supply was its foundation on private profit-making. The present system of coal mining and distribution, Sir Richard Redmayne had said, was extravagant and wasteful, and, according to Mr. Webb, it was this system, or want of system, which made coal mining, the marketing of coal, and its distribution, the sport of individual enterprise and competition for profit, without union of aim or co-ordination of effort, each of the jostling rivals seeking and being tested by merely private gain. Nationalisation alone could meet all the necessities of the position; it alone could improve the position of the miners in regard to housing, accidents, special disease and infantile mortality; it was the only means of dealing economically and efficiently with the nation's coal resources; it was also the only means of ensuring that the coal be supplied to consumers regularly and at the lowest cost. Mr. Webb then dealt with the question of compensation under nationalisation and estimated that the amount of Government stock that would be issued might be between 200,000,000*l.* and 300,000,000*l.*, subject to a considerable recoupment by the railways in respect of the private wagons taken over. For management, there would be at the head of the Administration, and, directly responsible to the House of Commons, a Minister for Mines; the Minister would preside over a department adequately staffed for dealing with the scientific and mechanical, the medical and social, and the commercial and financial sides of the work. The Minister would have the counsel and criticism of a permanent and authoritative National Coal Council. The coal districts would each be administered by a district superintendent, appointed by the Minister of Mines and assisted by the counsel and criticism of a local coal council. The executive management of each pit or mine would be, as now, in the hands of a responsible officer, duly qualified, and appointed by the Minister of Mines, with the advice of the local mines council. From top to bottom there should be the fullest possible publicity.

Professor Graham Wallas, London University, outlined the difficulties which the State would have to meet in regard to the appointment, discipline, promotion and control of probably 1,200,000 persons, should the coal mines be nationalised; posts and promotion might be given as a reward for political work or political subscriptions; the service might become a family affair. To the State, the appointment and promotion of manual workers to a service so large and complex as coal mining would be a comparatively new problem. An essential difference between coal mining and other industries consisted in the fact that the existing coal deposits when once exhausted could not be renewed, and each generation of the inhabitants of the country had to decide how far it would prefer the interests of its successors to its own interests.

Professor J. H. Jones, Glasgow University, said there was a strong *prima facie* case for the nationalisation of the coal industry. The industry was essential, but unlike essential industries now under public control it was inherently competitive; the product was concrete and tangible, and a large proportion was exported. No industry appeared yet to have been nationalised which possessed these features; there was, therefore, no precedent to estimate the probability of success. The coal industry should be reorganised in such a way as to enlist, and not suppress, initiative, and to direct it into the proper channels. This was not likely to be effected by nationalisation, which tended to create an atmosphere inimical to the growth of personality. But reorganisation of some kind, apart from being inevitable, was highly desirable. His own prejudice, on the whole, was in favour of nationalisation, but he felt that in the present instance, for the first time in the history of the country, there was an opportunity for experimental legislation, and it seemed a pity that there should be a leap in the dark when one could walk forward step by step and feel one's way.

STEEL WORKS MACHINERY.

At the meeting of the Sheffield Society of Engineers and Metallurgists, held on February 10 last, a paper dealing with the development of steel works machinery was read by Mr. W. Hands. In opening the proceedings the President, Mr. T. W. Willis, referred to his own experience of Sheffield manufactures extending over about 50 years and contrasted the old methods employed in his early years, with the recent developments about to be described by Mr. Hand. The following is Mr. Hand's paper :—

NOTES ON THE DEVELOPMENT OF STEEL WORKS MACHINERY.

By Mr. T. W. HAND, Chief Engineer,
Messrs. Davy Brothers, Limited.

THE development of steel works machinery may be said to be largely influenced by the well-known law of "supply and demand," since, whilst the users' every endeavour is devoted to more efficient production, the very existence of the designing engineer is dependent on his ability to develop suitable machinery for this purpose.

Generally speaking it must be admitted that prior to the war period such machinery as that now under consideration had reached a somewhat higher development in America and certain Continental countries than that obtaining in our own country.

The author does not attribute this state of affairs in any sense to a higher degree of intelligence in the countries named, but rather to the greater facilities for intensified and specialised production which justified the installation of more elaborate plant.

It appears to be now fully realised that to reach and maintain a steel production in this country commensurate with our position amongst the nations of the world, high outputs must be obtained. Whilst great credit reflects on the management of many of our steel works for the truly remarkable results recently obtained from machinery of far from modern construction, it is pleasing to note the possibilities of the future have been accurately gauged, as is evidenced by the provisions for continuity of operation which have been provided in many of the new plants now being installed.

It has occurred to the author since deciding on the title that full consideration of the subject is quite beyond the scope of a single paper, and it is therefore proposed to limit this to discussion of those sections of steel works plant with which he has been more closely associated, the examples illustrated being, however, typical of progress effected throughout steel works machinery.

In reviewing the developments which have been made in our steel works during the war period, it is very obvious that essentials had been well understood, as few new principles have been evolved. The improvements introduced consist of more complete development of well-established practice, continuity of operation being ensured by improved construction and a keener appreciation of the necessity of selecting the most suitable materials for a given duty.

This being a joint society of engineers and metallurgists the present appears to be too good an opportunity to be lost for emphasising the importance of this consideration, and the author would suggest that hearty co-operation in this respect would ensure the best results possible.

It is proposed to pass over such features as power generators, as such plant both as regards boilers and generators has formed the subject of separate and very valuable papers already given before the various engineering societies. It is interesting to note, however at this stage that with the exception of certain works at which blast-furnace gas is available under favourable conditions for use in internal-combustion engines, the steam turbine has now become universal for this duty, the tendency being to centralise power generators in increasingly large units.

For transmission of energy throughout the works, three principal agencies are utilised, viz., steam, hydraulic and electrical energy, the latter, owing to the many very important improvements which have been effected in the construction of motors and control gear, is now being employed for duties for which, only quite recently, it would have been considered altogether unsuitable.

Whilst the extended use of steam for works purposes is rapidly being discarded, considerable use of hydraulic power is still inevitable in all steel works, and an inspection of improvements which have been effected in both generation and distribution will no doubt be considered of some interest.

FIG. 1. TYPICAL BATTERY OF HYDRAULIC PUMPS.

The installations in most general use consist of motor-operated reciprocating pumps delivering into the works' mains, suitably loaded storage accumulators being installed in series. The capacity of these latter is such as to cope with sudden heavy demands, the pumps being proportioned for the regular supply of the total quantity of water which may be required over a longer period.

Fig. 1, above, illustrates a typical battery of hydraulic pumps, the principal characteristics of each unit being as follows :—

Driving motor : 200 h.p., 485 r.p.m.
Working pressure : 1,500 lb. per square inch.
Single reduction gear with double helical machine-cut teeth, totally enclosed and provided with continuous oil circulation.
Valve chambers and pump barrels of forged steel with renewable bronze valves and seats arranged for quick removal.

The importance of the last feature will be fully appreciated when it is realised that at such a pressure as that under which these pumps operate, the maximum possible velocity of water is 472 ft. per second, and in the event of a small particle of solid matter being deposited on a valve seat at the moment of closing, it is quite possible that the very minute opening between valve and seat may pass water at high velocity with great erosive effect. Needless to say, for the reason just stated, the materials of which pump valves and seats are manufactured should be most carefully studied.

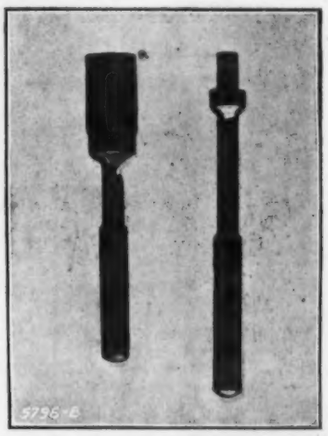
In the modern type of accumulator all external guide framing is dispensed with, the outer surface of the hydraulic cylinder being turned to form a continuous guide over which the bored central portion of the bottom casting of the loading tank works.

The operation of the hydraulic pumps is controlled by the rise and fall of the accumulator, the pump motors being automatically stopped on the accumulator reaching the top of its stroke and restarted at a predetermined point in the descent.

Reverting to Fig. 1, the control panels will be seen mounted on the elevated platform on the left of the illustration, these control gears being of the contactor type operated by master switch engaging with tappet levers on the accumulator. This method of control may now be looked upon as standard advanced practice, as the pumps are only in motion when pressure water is being called for, and the wear and tear on the pump parts is in consequence minimised. Light load losses of the operating motor are also eliminated.

The overall efficiency, or in other words the ratio of water horse-power to input of motor, for such a pump unit as that illustrated may be taken as 75 per cent. to 80 per cent.

Hydraulic mains and distributing valves have also received their due share of attention within recent times owing to the enormously increased use of hydraulic machinery during the war period, and when it is realised that under average conditions about 25 per cent. of the water pumped is lost by leakage through faulty valves,



Phosphor Bronze. *Nickel Steel.*

FIG. 2. HYDRAULIC VALVE SPINDLES.

it will be agreed that the very best working valve procurable is a first-class investment even at enhanced cost.

Fig. 2 is interesting in this respect, the illustration representing two hydraulic valve spindles of phosphor bronze and 25 per cent. nickel steel respectively, the erosive effect of high velocity leak-water impinging on certain portions of spindle immediately below valve seat being very clearly shown.

The choice of a suitable working pressure is dependent on several factors, e.g., in a self-contained plant under good supervision pressure up to 1,500 lb. per square inch will be found perfectly satisfactory, and cost of machinery, pipes, valves, &c., reduced, as these items will naturally be of smaller dimensions.

For distribution, however, throughout a large steel works where many machines have to work under conditions far from ideal, and at times with scant attention, a pressure of 750 lb. per square inch will be found more suitable owing, of course, to the less destructive effect on valve seats, ram packings, &c.

Whilst considering hydraulic power, it would no doubt be useful to review recent developments of an application of particular interest to Sheffield engineers and metallurgists, viz., the hydraulic forging press. Of all the machinery in use in our large works it may be truly said that none has played a more important part than the forging press during the strenuous war period, such presses having been used for the production of all classes of forgings from aeroplane parts to guns of the largest calibre.

With the continued demand for higher production, additional heating furnace capacity has been arranged for in many cases, resulting in more continuous operation, and all the skill and experience of the press designer has been called for in developing presses suitable for this more arduous duty.

Also owing to the constantly increasing cost of fuel, economical working and rapidity of action is of the utmost importance, the latter consideration vitally so, as far more fuel is used in heating the forging than is required for generation of energy to operate the press, and increased speed of working naturally allows of more work being done in a single heat.

Regarding the operation of forging presses, it may be safely stated that the steam hydraulic intensifier has now become universal owing to its simplicity of construction and capacity for speed. The necessity for generation of steam required for this type of press has been at times objected to, but such objections are seldom valid, as most forge reheating furnaces are notoriously inefficient, and the whole of the steam required for operation of the intensifier can generally be raised from the waste gases from the furnaces by installation of suitable waste-heat boilers.

Although the foregoing type of installation is usually permissible, occasions arise where forging presses are

installed for purely cogging purposes, and as continuous furnaces are naturally most suitable for heating the material so operated upon, and there being no available waste heat from this type of furnace, it is necessary to instal a steam boiler plant or alternatively high-pressure reciprocating pumps for the operation of the press.

It may be reasoned (not without truth) that this method of operation possesses certain advantages, inasmuch as the pumps may be operated by electric motor taking current from a central station generating electricity at low cost, and many such installations are now working quite satisfactorily.

An interesting example is a 4,500 ton press at the Terni Steel Works, in Italy. The high-pressure water for operation of this press is supplied by two 1,500-h.p. pump units driven by water turbines, the latter being in turn operated by low-pressure water from falls in the adjoining hills.

Taking into account, however, the greater complication of the system resulting in multiplication of working parts, with the combination of hydraulic valves

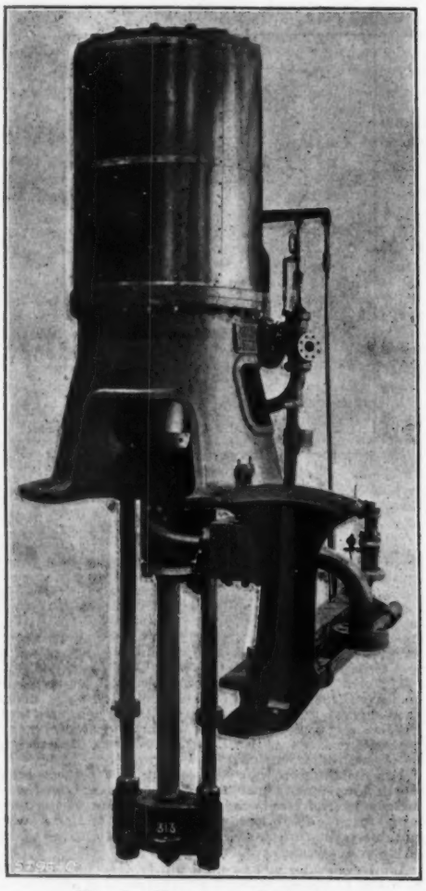


FIG. 3. HYDRAULIC INTENSIFIER.

operating under high pressures and the impossibility of attaining such a high speed of operation with this form of installation, the more simple and direct steam hydraulic intensifier is coming more and more into favour.

Some detailed consideration of progress which has been made with this most useful form of driver will no doubt be of interest.

In the type of steam intensifier usually employed until quite recent times the hydraulic cylinder is situated above the steam cylinder and supported in a cross-member connected by tension columns to the steam cylinder below, a prolongation of the piston rod forming the ram for the high-pressure hydraulic cylinder. This construction, as is well known, involves objectionable features, in particular the impossibility of preventing vibration from the press being transmitted to the intensifier owing to the cross connecting pipe being coupled at points where such vibration is most pronounced and also the trouble experienced through transmission of heat from steam to hydraulic units owing to the use of a common piston rod.

Obviously under war conditions with consequent intensified production these objections have claimed serious consideration, and a new type of inverted steam intensifier has been designed and put into commission with most gratifying results. Fig. 3 illustrates this intensifier in detail, whilst Fig. 4 shows its adaption to a 1,000-ton forging press.

Reverting to Fig. 3, it will be seen that the hydraulic cylinder is mounted in a stool below the steam cylinder and the upwardly working ram connected to the steam piston by means of two side rods and a bottom crosshead. The many advantages of this arrangement will be at once apparent, and may be summarised as follows :—

1. Perfect stability of the intensifier.
2. Increased output owing to higher speed of working possible.
3. Reduced maintenance owing to conditions of working above referred to.
4. Improved accessibility for examination, adjustments, lubrication, &c., and longer life of the packings due to complete isolation of hydraulic and steam units.
5. Better access for cranes around press due to abolition of overhead pipes. This feature will be readily appreciated by reference to Fig. 4.

Whilst considering the design of the steam intensifier, it will be interesting to study the possibilities of economising the steam used, the importance of this having been more emphasised of late owing to present and anticipated future difficulties regarding coal supplies.

In order to minimise first cost such intensifiers are usually designed for high steam pressure, and as the gradually increasing load due to resistance of the forging necessitates maximum pressure at the end of the stroke, expansive working has not been possible with a single cylinder. The new inverted intensifier, however, lends itself admirably to a compact tandem compound arrangement, and this principle has been introduced in an intensifier designed by the author, and to be shortly put to work in connection with a 1,000-ton press. This intensifier is so proportioned as to give powers up to three-fifths of full load on the compound system ; beyond this power high-pressure steam is automatically admitted to the low-pressure cylinder, which then operates in the ordinary manner as a simple intensifier. The power obtainable from the compound arrangement will, generally speaking, cover two-thirds of the total press demand, and it is anticipated that the steam required for operation of the intensifier will be reduced by at least 25 per cent. over the whole series of operations.

It will be well, however, to point out at this stage that by far the greater portion of steam wasted in an intensifier is due to careless operation, this being explained as follows :—

The capacity of a steam intensifier must be of necessity equal to the maximum penetration required over a single pressure stroke of the forging press, and in order to attain the minimum steam consumption it is imperative that the height of the top forging tool relative to the work should be adjusted from time to time so as to keep the clearance between tool and work as little as will allow of efficient manipulation. Otherwise, under usual conditions of working, a considerable portion of the intensifier stroke will be absorbed without performance of useful work.

Unfortunately, under actual working conditions, this adjustment is frequently neglected, and although various devices have been tried for compelling the press operator to return the intensifier steam piston to its bottom position before making a repeat stroke, experience has proved such contrivances valueless, as in any case the forgeman will not allow the continued use of any apparatus which interferes in the least degree with the free movement of the press. This line of argument is certainly permissible, as the primary object of a forging plant is to produce forgings expeditiously, and it is obvious that any attempt at steam economy must be made on interior lines and arranged in such manner as to be undisturbed by human interference.

With this end in view the author has developed an entirely new system of steam distribution which, paradoxical as at first thought it might appear, results in an economy of steam, which increases relatively with careless operation. This latter claim is easily explained, as the special control gear referred to allows of the recovery of a very considerable proportion of the steam which would be otherwise exhausted to atmosphere. Several advantages of press operation are also derived inasmuch as descent of the steam intensifier steam piston is accelerated, resulting in the press head with top tool being lifted from the work more promptly, and there is also a decided tendency to keep the intensifier steam piston at the bottom of its stroke, which it is obvious is the most desirable position for economical working.

It is not unlikely that this steam-saving gear, combining as it does increased speed of press operation, may meet all practical requirements, but in the event of the greatest possible economy being required, there is no doubt that its combination with the compound system would effect an overall economy of quite 50 per cent. of the steam used. As regards the forging press itself, the improvements effected result principally from closer study of all details influenced by strength, rigidity and continuous operation.

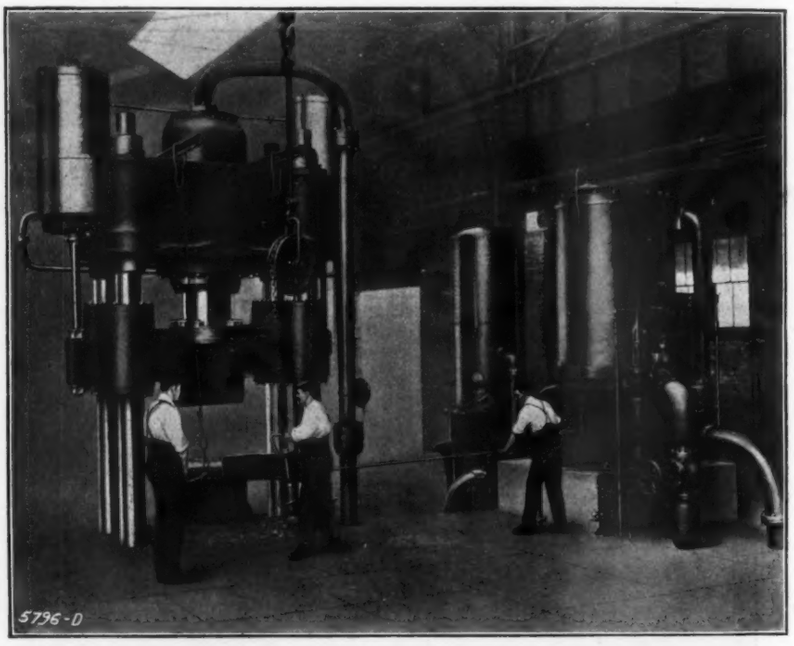


FIG. 4. INTENSIFIER APPLIED TO A 1,000-TON FORGING PRESS.

An improved control gear has been applied to the steam drawback cylinders of the press with most gratifying results, about 25 per cent. of the steam formerly used being economised, and far more important still, the objectionable pause which has always previously been experienced on commencing to lower the crosshead has been entirely eliminated.

Summing up, the author would suggest that the forging press has received its full share of consideration during the strenuous times we have just passed through, resulting in the production of a tool with capacity limited only by heating and handling facilities of the material to be worked.

As the production from a forging plant is largely dependent on efficient and ample furnace capacity, it is obvious that the latter should have due consideration. The coal-fired furnace appears to be more generally favoured, particularly in the Sheffield district, and it must be admitted that this type of furnace possesses distinct advantages, as apart from any superior claims, real or imaginary, regarding internal atmosphere, it is possible to generate the whole of the steam required for operation of the plant by installing waste-heat boilers on the furnaces.

Fig. 5 illustrates a typical installation, the boiler indicated being of the "Blake" type, which has been very extensively adopted with most successful results. This boiler will give an evaporation of 4 lb. to 5 lb. of water from and at 212 deg. F. per pound of coal fed into the heating furnace grate, or 9 lb. if coal is fired direct by means of the emergency hand-firing grate under the boiler.

This boiler is particularly suitable for the duty under consideration, being simple in design and of maximum strength owing to truly circular construction of all parts. It has wet-back combustion chamber and large area through the fire-box, combustion chamber and tubes, allowing a free natural draught.

It is very readily and cheaply installed, being built close up to the furnace, thus getting full advantage of all surplus heat, and as all gases from the furnace may be taken through the boiler, a large brick-lined furnace

stack is unnecessary, a light boiler chimney mounted on the boiler smoke-box sufficing for final exit of products of combustion.

In spite of the possibilities just referred to, however, the claims (for greater economy) of the gas-fired furnace cannot be ignored as obviously, other conditions being satisfactorily met, it is more economical to generate steam by direct firing of high-class boilers than is possible through a heating furnace. The advantages for and against both types of furnace warrant full investigation, particularly at the present time, in view of the relatively high cost of fuel.

It has been suggested that it is impossible to produce gas and deliver it to the furnace without free air, the excess resulting in an oxidising flame, such conditions becoming aggravated when the furnace doors are opened to draw the charge. The coal-fired furnace has also been credited with the possibility of more certain control with nearer approach to neutral conditions.

The author would suggest that a free interchange of ideas on this subject might assist in reaching more definite agreement, as undoubtedly much experience has been gained during the last few years with all types of furnace, and it would appear that for heating all classes other than alloy steels, the question really settles down to a matter of relative cost per ton of steel forged.

The following performance of typical press plants will perhaps be of interest :—

2,000-ton steam intensifier press served with five coal-fired furnaces, each equipped with one high-pressure "Blake" waste heat boiler; 200 tons of shafting for standard ships, &c., per week, with a total fuel consumption of 20 cwt. per ton of forgings produced. On other classes of work requiring more re-heating, the fuel consumption worked out as follows :—

For gun forgings, connecting rods, &c., 2 tons to 4 tons of fuel per ton of forgings produced.

Considering the capacity of a press of this power in more detail, the following examples will no doubt be of interest.

A marine shaft, 19 in. diameter by 28 ft. long, with 38 in. diameter collar at one end, has been forged complete in one heat from a 50-in. ingot.

A plain propeller shaft, 14 in. diameter by 40 ft. long, has also been completed in one heat, being under the press about 2½ hours altogether.

Very little data is available from which the relative economy of coal and gas-fired forge furnaces can be compared, but at one works where gas reheating furnaces are used with presses of powers ranging from 1,200 tons to 3,000 tons, employed on all classes of work, including standard ship shafts, light rotor wheels, gun jackets, &c., records show the average fuel consumption to be about 1½ tons to 1¾ tons per ton of forgings, this figure including annealing and steam raising. Some portion of this latter is derived from waste heat boilers on the furnaces, and the owners of the plant referred to consider the gas furnace in all respects quite equal if not superior to the coal-fired furnace for such duty.

Fig. 5.

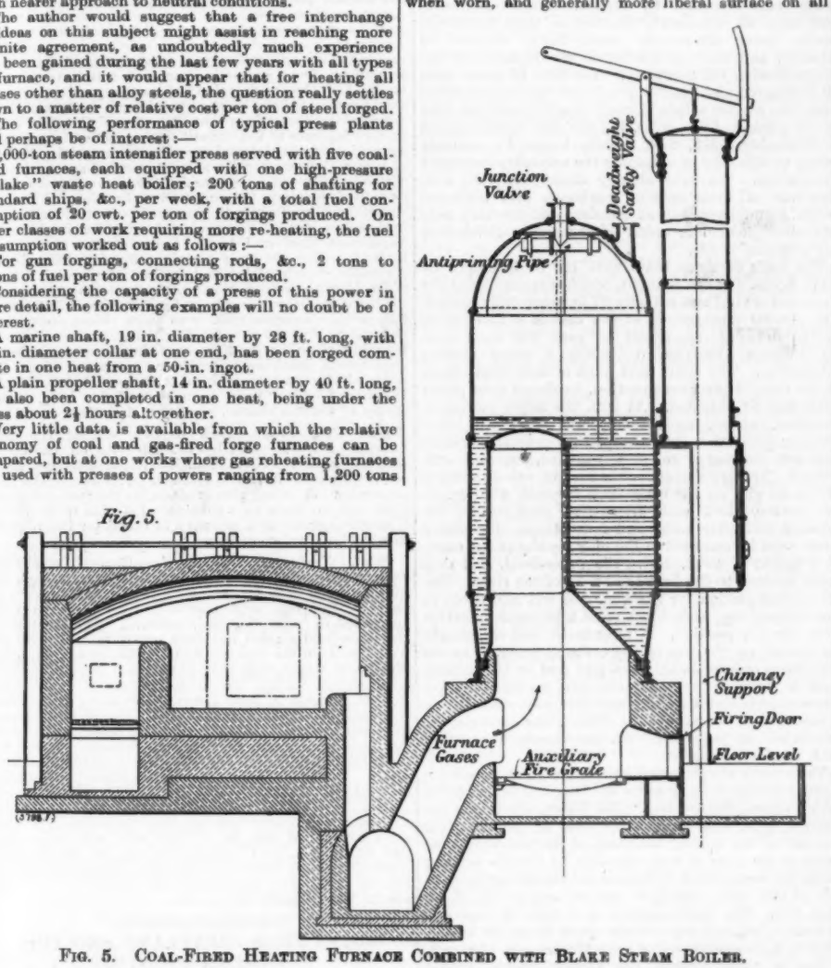


FIG. 5. COAL-FIRED HEATING FURNACE COMBINED WITH BLAKE STEAM BOILER.

For certain classes of work where ingot sizes are standardised, a combination of continuous furnaces and ordinary forge-reheating furnaces has been used with most satisfactory results, the continuous furnace being used for heating the ingots for such forgings as may be worked up from a single heat, and the ordinary furnaces employed for special-sized ingots and reheating purposes generally.

A 2,200-ton forging press thus equipped has produced in a week 275 tons of miscellaneous forgings consisting of plain round and square bars, shafts, gun jackets, &c., with a fuel consumption of 11 cwt. to 12 cwt. per ton of forgings, this figure including coal used for steam raising with direct-fired boilers.

The following further examples will give some idea of the output which may be obtained from presses of smaller power :—

1,000-ton press producing gun tubes, jackets and breech blocks, 91 tons of forgings per week of 10½ shifts.

500-ton press finishing tank-gun tubes and jackets from 9½-in. cogged blooms, 52 tons of forgings per week of 10½ shifts.

As an illustration of the output obtained by our American Allies, it will no doubt be of interest to state that a 1,000-ton press said to hold the record in the United States, has cogged and rounded up into 12¾-in. diameter shell bars 105 tons of forgings in three 8-hour shifts from 26-in. octagon ingots, 5 tons to 6 tons in weight.

For reasons which are now well understood the forging press is fast displacing the steam hammer for most purposes other than very light forgings, which are usually produced under hammers of powers up to about 40 cwt. It is realised, nevertheless, that progressive opinion is seldom unanimous, and as the heavier hammer is still receiving some measure of support, the engineers' attention has naturally been concentrated on improved construction demanded by more arduous duty.

This improved construction comprises massive cast steel standards, means for adjustment of tup slides when worn, and generally more liberal surface on all parts subject to wear. The dimensions and weight of anvil blocks have been substantially increased and renewable cast steel tool holders fitted to the upper surfaces of blocks.

The steam hammer under the best of conditions is more wasteful of steam, the consumption being about double that of a forging press of corresponding power, and in view of this knowledge, attempts at further economy are now being made by fitting suitable rings to operating valves and provision of some simple form of expansion gear for cutting off the top steam at a predetermined point of the downward stroke.

(To be continued.)

MUNICIPAL ENGINEERING.—A short course on municipal engineering will be held at University College, London, during the summer term. It will be open to ex-service men who are in civil life employed in municipal engineers' offices as pupils or assistants. The course will include lectures on Water Supply and Waterworks Construction; Sewerage and Sewage Disposal; Road Construction and Maintenance; Preparation of Specifications, Quantities, Estimates, &c., and of Parliamentary Plans. The lectures will be accompanied by drawing office practice in the design of municipal engineering structures, and the preparation of drawings. The course will last about eight weeks; it will begin on Tuesday, May 13, 1919. Further particulars may be obtained from the Secretary, University College, London (Gower-street, E.C. 1).

NOTES FROM THE NORTH

GLASGOW, Wednesday.

Scotch Steel Trade.—Now that the new scale of prices for steel material has been announced a certain amount of anxiety has been removed and buyers know exactly where they stand, for the next two months at least. The conditions of industry generally are unprecedented, but it is anticipated that it will not be very long before we settle down to the new *regime* in the same way as we faced the abnormal times which we experienced during the past few years. All over the world there is a very large amount of material required, both for new projects and for renewals, and a good share of the demand is expected to find its way to this market. Competition for foreign business will be keen as prices for export are "free." The matter of transport is one of the main difficulties at the moment, but given reasonable shipping facilities, and slightly more favourable freights than at present rule, a strong bid will be made by the local steel-makers to secure a goodly portion of the export trade. For home delivery the following are the prices which have been arranged for the months of May and June, and they likewise apply to undelivered orders on hand: Ship plates, 17*l.* 10*s.*; angles, 17*l.*; boiler plates, 19*l.* 10*s.*; joists, 17*l.*; round bars over 3 in., 17*l.* 12*s.* 6*d.*; round bars under 3 in., 19*l.* 17*s.* 6*d.*; and blooms, 19*l.* per ton, all delivered in the Clyde area, but exclusive of cartage. Business on hand consists of a fairly good demand for ship and boiler plates, but there is rather less doing in sectional material, and the general export trade is slow to open out. The prices of black steel sheets have been fixed as follow: Over ⅛ in., 21*l.* 10*s.*; ⅛ in. and ¼ in., 22*l.*; under ¼ in. to 13-gauge, 22*l.* 2*s.* 6*d.*; 13-gauge to 16-gauge, 2*s.* 6*d.* more; 16-gauge to 20-gauge, 5*s.* extra; 20-gauge to 24-gauge, 10*s.* extra; 24-gauge to 27-gauge, 1*l.* extra—all per ton, net, f.o.t. works, and for the home trade only.

Malleable Iron Trade.—The malleable iron makers in the West of Scotland continue to be well employed, and the number of orders on hand is very satisfactory. The bulk of the business at present going through is for the home market, and many of the consumers are in urgent need of material for various purposes. A steady demand prevails for bolt and rivet bars. Prices are being maintained at a high level.

Scotch Pig-Iron Trade.—The demand for Scotch pig-iron has been fairly good of late, but at the new level of prices—an advance of about 3*l.* per ton, from May 1—the output may receive a slight check. This is only likely to be of a temporary nature until things settle down to the new scale, as, with general shipping beginning to show signs of improvement, inquiries for all kinds of steel and iron are getting better. In the matter of export there is little signs of improvement just yet, but producers are sanguine of a revival in the near future. Hematite iron is now quoted at 9*l.* per ton, delivered at the local steel works.

West of Scotland Iron and Steel Institute.—The annual meeting of the West of Scotland Iron and Steel Institute was held on Friday, in the Royal Technical College, Glasgow, when Mr. M. L. Simpson presided. The annual report was submitted by Mr. Douglas A. MacCallum, secretary and honorary treasurer. Its adoption was moved by the chairman, and was duly approved by the meeting. The membership of the Institute at present stands at 504, being an increase of 62 over last year. Mr. W. H. Cathcart was presented with a number of volumes in appreciation of a paper on "The Welding of Iron and Steel," delivered by him to the Institute. Mr. J. H. S. Dickenson, of Messrs. Vickers', Limited, experimental research laboratory, read a paper on "Nickel-Chromium Steels," illustrated by diagrams and photographs on the screen.

Shipbuilding.—During the past month a great amount of activity has been evident in the shipbuilding yards of the Clyde, as is shown by the output, which consisted of 34 vessels totalling 85,774 tons. That figure is more than double the total for the month of March which was 40,242 tons, and, while not a record for the month of April, it stands second only to the corresponding month of 1913, when the total was 119,303 tons. Of course, the war years are omitted from comparison. For the four months of this year the Clyde shipbuilding output now reaches the respectable total of 88 vessels of 163,455 tons. During the past month there were 12 vessels launched of 5,000 tons or over, and of these the largest were the steamer Nuddea, 8,000 tons, and the steamer Masula, 7,500 tons, both by Messrs. Barclay, Curle and Co., Limited, Whiteinch, for the British India Company, London. Among the contracts fixed up during the month were eight barges aggregating 1,800 tons, to be built by Messrs. Alley and MacLellan, Polmadie.

CAPITAL AND LABOUR.—Lieutenant-General Sir Edward Bethune, K.C.B. (chief organiser), and Mr. T. Ernest Jackson (trade union and labour organiser), of the National Alliance of Employers and Employed, will address joint conferences of representatives of employers and delegates from trade unions at Newport (Mon.), on May 5; at Grantham on May 8; at Oxford on May 13; at Dudley on May 14; at Lancaster on May 19; at Bedford on May 20; and at Salisbury on May 30. The subject of discussion in each case will be "The Industrial Future." The National Alliance is aiming at forming joint committees of employers and trade unionists for the purpose of harmonising the relation between Capital and Labour. New committees are being formed every month in the large industrial areas, and in several cases industrial disputes have been avoided or shortened by the activities of these local committees. It is stated that already 23 committees have been formed in the chief industrial centres.

SHALLOW-DRAUGHT GUNBOATS FOR THE TIGRIS.

We illustrate, on page 572, two types of shallow-draught gunboats which were used with great success on the River Tigris in the Mesopotamian campaign. The larger vessel, shown in Fig. 1, is one of 12 ordered by Lord Fisher in February, 1915, and originally intended for patrol service on the Danube for the protection of Serbia, although they were designated "Large China Gunboats" to conceal their real destination. They were arranged to be constructed in pieces, shipped to Salonica, and thence transported by rail and re-erected on a tributary of the Danube in Serbia. It was decided that the vessels should not be armoured, but should be supplied with guns of sufficient power to outrange those of the Austrian monitors on the Danube, and should also have a higher speed than that of the Austrian vessels. When Bulgaria entered the war in October, 1915, and the Serbians were driven from the Danube, the vessels could not, of course, be used as originally intended, and it was then decided to rivet them up and employ them for other work. After some temporary longitudinal stiffening had been carried out, four of the boats were sent out to the Tigris, six to the Suez Canal, and two were used for submarine hunting off the East Coast of England. It is a noteworthy fact that the 10 vessels reached their foreign stations with only one slight mishap, which was easily put right.

The design of the vessels, which were named Aphis, Bee, Cicala, Cockchafer, Cricket, Glowworm, Gnat, Ladybird, Mantis, Moth, Scarab, and Tarantula, was placed entirely in the hands of Messrs. Yarrow and Co., Limited, Scotstoun, Glasgow, who supplied detailed designs of hull and machinery to the builders. The Ailsa Shipbuilding Company, of Troon, built the hulls and machinery of two vessels, Messrs. Barclay, Curle and Co., of Glasgow, the hulls and machinery of four vessels, and Messrs. Lobnitz and Co., of Renfrew, the hulls and machinery of two vessels. The hulls of two vessels each were built by the Sunderland Shipbuilding Company and Messrs. Wood, Skinner and Co., of Newcastle-on-Tyne, the machinery for all four vessels being supplied by the North-Eastern Marine Engineering Company, of Wallsend. During the construction of the gunboats the Admiralty were represented by Commodore S. S. Hall, R.N., and the engineering branch by Engineer-Commander P. Stocker, R.N. Engineer-Commander E. Bond, R.N., was appointed overseer.

Brief reference was made to these vessels in Sir Eustace Tennyson d'Eyncourt's paper on "Naval Construction during the War," read at the recent meeting of the Institution of Naval Architects, and drawings of them are reproduced on page 489 *ante*. The vessels are 230 ft. long by 36 ft. beam, and they were designed for a draught of 4 ft. when fully loaded. The hull is divided into 34 watertight compartments in order to allow for the flooding of several compartments without putting the ship out of action. All fittings, outfit and store articles are of the standard Admiralty pattern, so that the vessels can draw their stores from the dockyards in the usual way. As shown on the drawing above referred to, the ward-room and officers' quarters are situated in the fore part of the vessel, while the petty officers, and the greater part of the crew, are berthed aft. Although no attempt was made to keep out artillery projectiles the plating of the hull in way of the machinery and gun positions was made sufficiently thick to resist rifle and machine-gun bullets, and the results have shown the wisdom of this decision. In this connection it may be of interest to mention that during the Turkish retreat from Kut on February 26, 1917, three of these vessels, with two of the smaller type, made a dash up the river past the Turkish rearguard and attacked the main army with such good effect that what was previously an orderly retirement was converted into a rout. In passing the rearguard the vessels were exposed to heavy fire at close range, and every ship, although hit several times, continued its course. The Moth, which was last in the line, was hit eight times by shells, but was not put out of action. The armament consists of two 6-in. quick-firing guns mounted on the main deck, one forward and one aft of the superstructure, with magazines immediately behind them. A 12-pdr. gun is also mounted at each end of the battery deck, and six Maxim rifle-calibre guns are also placed on the battery deck in the positions shown in the drawing. Some of the vessels also carried a 2-pdr. pom-pom gun for defence against aircraft. A rangefinder and searchlight are mounted on the top of the conning-tower, and a crow's nest on the masthead is arranged to accommodate an observer when aeroplanes are not available for observation purposes. Double awnings and side curtains are fitted over the whole of the living spaces and the battery deck. Wireless apparatus is also carried.

The machinery consists of two sets of triple-expansion engines, driving twin screws working in tunnels provided with Messrs. Yarrow's patent hinged flaps. Steam is supplied by two Yarrow-type boilers arranged to burn either coal or oil fuel. The coal bunker capacity is 35 tons, and the oil fuel capacity 54 tons. In trials on the measured mile the average speed obtained was 18 m.p.h. with the designed draught of 4 ft., and the best speed, of 20 m.p.h., was obtained by the Ladybird on a draught of 3 ft. 7 in. The highly satisfactory results obtained with these vessels amply justifies Lord Fisher in giving Messrs. Yarrow a perfectly free hand in their design.

The vessel illustrated in Fig. 2 is one of 16 smaller "China" gunboats, of which 12 were ordered by the Admiralty in February, 1915, and four in December of the same year for service on the Tigris. These boats were designed by Messrs. Yarrow and Co., and were all completely erected at their Scotstoun works, being afterwards taken down, shipped to Abadan, and there re-erected on the premises of the Anglo-Persian Oil Company. The first 12 boats were all completed and handed over to the naval authorities ready for service within thirteen months from the time of the placing of the order, but the four boats ordered in December, 1915, took slightly longer to complete owing to difficulty in obtaining the necessary transport to Abadan. We have already dealt* with the construction of these smaller gunboats, and their re-erection and launching at Abadan, but we may now add some particulars which could not be published in our previous article.

The hulls of these boats were 120 ft. in length by 20-ft. beam, and the draught, which was stipulated not to exceed 30 in., was actually 27 in. when fully loaded. The general arrangement of the vessels is well shown in the drawing reproduced on page 488 *ante*, from Sir Eustace Tennyson d'Eyncourt's paper already referred to. The boats were built of mild steel, since, at the time of their construction, hardened steel plates could not be obtained. As with the larger gunboats, described above, no attempt was made to resist artillery projectiles, but the plating generally was of sufficient thickness to stop machine-gun and rifle bullets. The armament for the first 12 vessels consists of a 4-in. gun on the main deck forward, a 6-pdr. on the battery deck with alternative positions at the forward and after ends, and four Maxim rifle-calibre guns could be mounted in the military top of the mast, at a height of 40 ft. above the water-level, and thus could be used to fire over the banks of the river. The fire-control station for the 4-in. gun was also fitted in the military top, with direct voice tube communication with the gun position. A rangefinder and searchlight are placed on the top of the conning-tower. On the four boats ordered later, the 6-pdr. gun on the battery deck is replaced by a 12-pdr. gun mounted at the forward end, and a 2-pdr. pom-pom anti-aircraft gun is mounted at the after end. This is the arrangement illustrated on page 488. All the vessels were fitted with wireless apparatus.

The vessels are propelled by a set of triple-expansion engines driving a single screw working in a tunnel fitted with Yarrow's hinged flap. The boiler, which is of the Yarrow type, can burn either coal or oil fuel. On account of the muddy condition of the water in some parts of the river it was necessary to provide settling tanks for reserve feed, and these are placed one on each side of the boiler casing, as can be seen in Fig. 2, on page 572. The fuel capacity is 5 tons of coal and 10 tons of oil, and the average speed of all the vessels tried on a measured course near Abadan was 10 m.p.h.

One of these vessels, the Firefly, which is that shown in the photograph reproduced in Fig. 2, on page 572, accompanied General Townshend's advance to Ctesiphon, and was captured by the Turks during the retreat from that place owing to the fact that her boiler was put out of action by shell fire. The vessel was, however, recaptured on February 26, 1917, by the flotilla of large gunboats in the action referred to in our description of the latter vessels. She was quickly repaired, and again put into service. Several of these small gunboats accompanied the advance to Baghdad, and others were used for policing the lines of communication on the Tigris.

DIRECTORY OF PAPER MANUFACTURERS.—A copy of the 1919 edition of the "Directory of Paper Makers of the United Kingdom" has just come to hand from the publishers, Messrs. Marchant, Singer and Co., of 47, St. Mary Axe, London, E.C. 3. This directory, which has been carefully revised and brought quite up to date, contains a vast amount of information of value to printers, stationers, and all other buyers of paper. The chief features of the directory are the lists of paper-makers and paper-makers' representatives, and the lists of water-marks and trade names, but much other useful matter is included. The price of the book, which contains 260 pages bound in paper-covered boards, is 2*s.* net, or 2*s.* 6*d.* post free to any part of the United Kingdom.

* See Engineering, vol. civ, page 429.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Efforts made to fix a basis price to take effect on the removal of Government subsidies have apparently met with little success, and a good deal of forward business is consequently being held up. Advances on pig-iron have been notified amounting to as much as 3*l.* 17*s.* 6*d.* per ton on the recent maxima, but this is rather the exception than the rule, the trade generally favouring an advance of 45*s.* on old contract tonnages and 50*s.* for all new business. Staffordshire prices have advanced 3*l.*, making forge 8*l.* and foundry 8*l.* 5*s.* The scarcity of pig-iron and bar-iron continues. Bar-iron is so badly wanted that contracts are being arranged regardless of price. The reaction of these advances on steel prices is problematic. Steelmakers forecast an advance averaging 5*l.* per ton, and, though the revised prices would appear prohibitive considering American quotations, steel is so badly wanted in many sections of industry that users will be compelled to buy. Armament manufacture is very quiet, and shipbuilding requirements are on only a moderate scale, but the armament firms generally compiled satisfactory order books for the resumption of peace production and slackness is confined to the open-hearth furnaces, which are working three days a week. One of the most satisfactory features of the current trade position is a marked expansion in the demand for railway material. Makers of locomotive parts, rails, axles, tyres and springs report a steady influx of orders, and there is every prospect of sustained activity for many months ahead. Despite the difficulties of extending overseas connections, export business is steadily improving, largely for implements, implement steel and tools. Some of the best orders booked during the past fortnight are for deliveries to Australia, South Africa and India. Montreal is taking a considerable output of sheep shears, tools are required for Bombay, Ottawa, and saws for Penang and Melbourne. Competition compels makers to quote prices pretty near the margin, but the quality of British goods appears to be standing them in good stead. Makers of agricultural implements anticipate brighter prospects from the removal of import prohibition of various classes of tools. Important orders have been booked for hoes, rakes, shears of various classes, scythes and sickles.

Hull Coal Trade.—Hull exports during the past quarter have decreased by 162,296 tons on the corresponding period of 1918. This is attributed to suspension of all shipments from the Humber ports during the past six weeks. A strong plea is made for the removal of the Hull coal embargo, as a substantial section of the South Yorkshire productive industry is based on the requirements of neutral countries.

South Yorkshire Coal Trade.—General conditions remain very much the same as a week ago, though the outputs have been larger, owing to the general resumption at the pits and manufacturing concerns have succeeded in improving their reserves. The shortage in the household section has been partly remedied by the use of some of the steam output for household purposes. Merchants report that they are getting more up-to-date with orders, though the sudden return of wintry conditions brought a fresh influx of business which they were only partly able to deal with. For all descriptions of steam fuels, the demand continues brisk, and in most cases the supply falls short of requirements. Slacks are in rather better supply and are easily fetching maximum prices. Cokes of all descriptions are scarce and supplies difficult to obtain. Quotations:—Best branch hand-picked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—With the restoration of freedom of transactions trade is expanding and prospects, so far as Cleveland pig-iron is concerned, must be regarded as bright and encouraging. Makers are already very well sold, some of them in fact having disposed of the whole of their output to the end of June. As Cleveland pig-iron is now regarded as the cheapest iron in the country it is not surprising to find buyers very keen to enter into contracts, and quite prepared to pay half-a-crown above the minimum selling prices recently fixed by producers. Demand on both home and foreign account is very heavy, and if it continues, no doubt great effort will be made to increase output by blowing-in more furnaces, but the problem of ore supplies is a great obstacle to such a step. Native ores are insufficient, and any material addition to production would necessitate more extensive use of imported ores. Nothing below 142*s.* 6*d.* is now named for No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge, and 146*s.* 6*d.* for No. 1. Some makers were, in fact, inclined to hold out for 2*s.* 6*d.* above these rates.

Foreign Ore.—There is a little more passing in foreign ore, but consumers continue to hold off buying in the belief that conditions will turn more in their favour. Freights keep well above the parity rate but ore users expect them to fall.

Hematite Iron.—East Coast hematite iron is no longer abundant, extensive purchases for South Wales having largely taken up the supply. Buyers from that quarter have come into the market owing to the comparative cheapness of East Coast brands, mixed Nos. being still

172*s.* 6*d.* and No. 1 quoted 175*s.*, the carriage to South Wales being 15*s.*; whilst South Wales hematite is quoted 200*s.* East Coast hematite, however, shows a very marked upward tendency, and immediate advance of 8*s.* or 10*s.* is generally looked for.

Manufactured Iron and Steel.—Business generally in finished iron and steel is by no means brisk. Shipbuilding and railway material continue in good request, but there is very noticeable slacking of demand for many other descriptions. Quotations, all round, however, are well maintained, and some advances have to be recorded, iron bars, and iron strip have risen 2*l.* 15*s.*, and steel hoops 2*l.* 10*s.* The following prices govern the home trade as from May 1:—Common iron bars, 20*l.* 10*s.*; marked bars, 23*l.*; strip iron, 21*l.* 15*s.*; steel strip, bridge and tank plates, 17*l.*; steel angles, 16*l.* 10*s.*; steel joists, 16*l.* 10*s.*; steel hoops, 23*l.* 5*s.*; and heavy sections of steel rails, 15*l.* No export prices have been fixed by producers, but plates are stated to have been sold at 18*l.* for shipment abroad.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Most collieries are fully stemmed until the middle of May, and buyers find it difficult to obtain even small parcels of either large or small steam Cardiff coals. Though collieries are well booked, temporary stoppages are still taking place owing to the insufficiency of tips at the local docks, and it happens here and there that in order to bring relief to other pits the Bristol Channel Coal Co-ordinating Committee order the shipment of a particular colliery's coals so as to effect a clearance of wagons and thus keep the particular pit going. Outputs, though better than last week, are still below the normal, and now that the miners are earning higher wages it is doubtful whether there will be much improvement, for an increase in pay has invariably led to a decrease in production. Dry, bituminous and washed coals are also scarce. The inland and allied demand remains heavy and exports to neutral countries are limited by the refusal of the authorities to sanction releases except in special cases. There is plenty of tonnage in the Cardiff, Penarth and Barry docks, and even if outputs increase it is considered doubtful whether the tipping capacity of the various docks would be able to cope with the work as already the loading facilities are taxed. A number of vessels have been waiting for cargoes for over a fortnight, and in some instances steamers waiting to load for neutral countries have sailed light after having been detained over a month. In other cases shippers have been refused licences for Cardiff coals and have been advised to send their boats to Swansea to load, where licences have been readily granted.

Newport.—Monmouthshire large and small coals of all descriptions are in good demand, and supplies are scarce, as the majority of collieries are booked up over the next fortnight. The tonnage position is good, and there are sufficient waiting steamers to keep exporters busy for the next couple of weeks. Transport facilities, however, are not able to cope with the work of bringing coals to the docks and returning wagons owing to a lack of engine power, while the tipping facilities, though better than at Cardiff, are not able to meet the requirements of exporters. The trimmers here have brought into operation a new system whereby they pool their weekly earnings. They have also thrown over coal foremen and have appointed a body of 16 supervisers to superintend the work of trimming. At the same time they offer no objection to a firm having a coal foreman of their own providing the firm pays him. Previously the custom was for the coal foreman to engage the gangs for loading vessels, and he was allowed to take a share of the earnings of the men.

Swansea Dockers' Strike.—No settlement has yet been reached in the stoppage of 1,000 general cargo workers at Swansea, and the prospects of an early agreement appear to be rather remote. The stoppage has now been in progress a fortnight, and so far has not spread to any other branch of dock workers. Separate meetings of the men and employers have been held, but no joint conference has taken place. The Ministry of Labour has now intervened and asked both parties to agree to a joint meeting to take place in London. The matter has been taken out of the hands of the Swansea workers and the London Executive of the Dockers' Union has taken over the question. The men, it is stated, have intimated their willingness to accept a new tariff on a flat-rate basis, to exclude "extras," and while the employers are not averse to a joint meeting they feel that no good can be gained by taking the dispute to London. Both sides appear to be determined to fight the matter out to a finish, and the men state that they are in a position to carry on the struggle into next year if necessary. Whether the Ministry of Labour will be able to bring the parties together remains to be seen. Meantime the trade of Swansea is suffering and already a number of boats have been diverted to other ports.

The Tin-Plate Trade.—Work in the tin-plate trade of South Wales is brisk, though operations are necessarily handicapped by a continued shortage of raw materials. The uncertainty of the labour position is still causing merchants some anxiety. The men have recently put forward an ambitious programme which is to be considered by the Industrial Council which has taken the place of the Conciliation Board. The men's demands number over 100 items, and the chief of these are a 35-hour week and a wage of 5*l.* 5*s.* per week for picklers, 3*l.* 3*s.* for assistant picklers, and 3*l.* 10*s.* for all helpers, including girls.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, May 2, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. Paper, "The Mechanical Properties of Steel, with some consideration of the Question of Brittleness," by Mr. W. H. Hatfield, D.Met., of Sheffield, Associate Member.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 2, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W., Lecturette, "Engineering at the Front," by Captain G. B. Paterson, A.I.F. Friday, May 9, at 7.30 p.m., Lecturette, "Pneumatic Tyres as Applied to Road Vehicles and their Automatic Inflation," by Mr. R. Barnfather, Junr.

THE BRITISH FOUNDRYMEN'S ASSOCIATION: LANCASHIRE BRANCH.—Saturday, May 3, at 4 p.m., in the College of Technology, Manchester, Annual Meeting and Election of Officers. After the election there will be a discussion on "Cupola Practice," and Mr. Haigh, of Wakefield, will speak.

THE SOCIETY OF ENGINEERS.—Monday, May 5, at 5 p.m., in the Rooms of the Geological Society, Burlington House, W. (entrance at the east end of the building in Piccadilly). The Proceedings will open with a social gathering of members and visitors (tea and light refreshments being provided), after which a paper will be read, at 5.30 p.m., on "Heat Treatment of Steel," by Mr. C. O. Bannister, F.I.C., Assoc.R.S.M.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Monday, May 5, at 8 p.m., a meeting will be held in the large Lecture Room at the Applied Science Department, St. George's Square, Sheffield, when the following paper will be discussed: "The Mechanical Properties of Steel, with Some Consideration of the Question of Brittleness," by Dr. W. H. Hatfield, A.M.I.Mech.E. Chairman: Mr. J. Rossiter Hoyle, Vice-President of the Institution of Mechanical Engineers.

THE INSTITUTE OF MARINE ENGINEERS.—Monday, May 5, at 6 p.m., a paper will be read on "Marine Air-Pumps as a Power Factor," by Mr. Harold Walker (Member).

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, May 6, at 5.30 p.m., Ordinary Meeting. Further discussion of the papers on "The Electrical and Mechanical Equipment of the All-Metal Cars of the Manchester–Bury Section, Lancashire and Yorkshire Railway," by Mr. George Hughes, M.Inst.C.E.; "All-Metal Passenger Cars for British Railways," by Mr. Francis Edward Gobey, O.B.E., Assoc.M.Inst.C.E.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, May 7, at 8 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C., when Mr. Charles Day will read a paper on "Diesel Engines." Thursday, May 8, at 7.30 p.m., at the Chamber of Commerce Hall, New-street, Birmingham, when Mr. E. Tilston will read a paper entitled "Two-Stroke Engines for Motor Cycles."

THE INSTITUTION OF SANITARY ENGINEERS.—Wednesday, May 7, at Caxton Hall, Caxton-street, Westminster, S.W., when a Sessional Meeting will be held. Subject: "My Two Years' Experience as Sanitary Inspector in H.M. Forces at Richborough," by Ex-Corporal F. G. Money, R.E. The president will take the chair at 7.30 p.m. Discussion will follow.

THE ROYAL SOCIETY OF ARTS.—Wednesday afternoon, May 7, a paper on "The Supply of Electricity" will be read by Mr. John Somerville Highfield, M.Inst.C.E., M.I.E.E. The chair will be taken at 4.30 p.m. by Mr. Alan A. Campbell Swinton, F.R.S., chairman of the Council of the Society.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 8, at 2.30 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Joint Meeting and discussion with the Iron and Steel Institute, when the following papers will be discussed: Mr. J. Bibby, "Developments in Iron and Steel Electric Furnaces"; Mr. W. H. Booth, "The Booth-Hall Electric Furnace"; Mr. H. A. Greaves, "Application of Electrical Energy to the Melting of Metals"; Mr. R. G. Mercer, "Electric Furnaces in the United Kingdom, 1918"; Mr. Axel Sahlin, "A New Type of Electric Furnace"; Mr. Victor Stobie, "Large Electric Steel-Melting Furnaces."

THE IRON AND STEEL INSTITUTE.—Thursday, May 8: 10.30 a.m., General Meeting of Members: The council will present their report for the year 1918; the hon. treasurer will present the statement of accounts for 1918; award of the Bessemer Medal for 1919 to Professor Cav. Federico Giolitti, Ph.D., of Turin; papers Nos. 6, 8, 3, 16, 17, will be read and discussed. 1 p.m.: The meeting will be adjourned. 2.30 p.m.: Joint Session (by invitation of the Institution of Electrical Engineers to discuss papers on Electric Steel Furnaces. The following is a list of the papers likely to be submitted: "Developments in Iron and Steel Electric Furnaces," by Mr. J. Bibby; "The Booth-Hall Electric Furnace," by Mr. W. K. Booth; "The Development of the Electric Melting Furnace," by Mr. D. F. Campbell; "The Control of Electric Arc Furnaces," by Mr. H. Coates; "New Type of Electric Furnace," by Mr. Axel Sahlin; "Large Electric Furnaces," by Mr. Victor Stobie. Friday, May 9: 10 a.m., General Meeting of Members: Papers Nos. 11, 10, 1, 2, will be read and discussed. 2.30 p.m.: Afternoon Session to read and discuss papers Nos. 15, 7 and 12. The following is the list of papers that are expected to be submitted: (1) Mr. J. H. Andrew, "Manufacture and Working of High-Speed Steel"; (2) Mr. J. O. Arnold and Mr. F. Ibbotson, "Molecular Constitutions of High-Speed Tool Steels, and their Correlations with Lathe Efficiencies"; (3) Mr. C. H. F. Bagley, "Modern Steel Metallurgy"; (4) Mr. G. Cesaro, "Note on the Liquidus in the Iron-Carbon Diagram"; (5) Mr. G. Watson Gray, "Estimation of Phosphorus in the Presence of Tungsten"; (6) Mr. L. Greiner, "Report on the Condition of Belgian Iron and Steel Work after the German Occupation"; (7) Mr. D. Hanson and Mr. J. E. Hurst, "Improvements in the Case-Hardening Process"; (8) Mr. L. C. Harvey, "Use of Powdered Coal"; (9) Mr. K. Honda, "On the Non-Allotropic Nature of the A2 Transformation in Iron"; (10) Mr. J. C. W. Humfrey, "Macro Etching and Printing"; (11) Mr. H. M. Howe, "A Review of Work of United States National Research Council"; (12) Mr. A. McCance, "Carburisation of Iron at Low Temperatures"; (13) Mr. A. M. Portevin and Mr. M. Garvin, "An Experimental Investigation of the Influence of the Rate of Cooling on the Hardening of Carbon Steels"; (14) Mr. K. Tawara and Mr. G. Asahara, "On Graphitisation in Iron-Carbon Alloys"; (15) Mr. G. Taylor, "Some Points in the Manufacture of Files"; (16) Mr. J. H. Whiteley and Mr. A. F. Hallimond, "The Acid Hearth and Slag"; (17) Mr. B. Yanecke, "Deoxidation, and the Influence of Lime on Equilibrium in the Acid Open-Hearth Furnace." In celebration of the Jubilee of the foundation of the Iron and Steel Institute in 1869, the Annual Dinner will be held this year at the Guildhall of the City of London, by kind permission of the City Corporation.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 9, at 5.30 p.m., a discourse will be delivered by Sir George Macartney, K.C.I.E. The subject will be "Chinese Turkistan: Past and Present." Afternoon Lectures, at 3 p.m.: Tuesday, May 6, Professor A. Keith, M.D., LL.D., F.R.S., Fullerian Professor of Physiology, Royal Institution, on "British Ethnology—The People of Wales and Ireland" (Lecture II). Thursday, May 8, Dr. H. S. Hele-Shaw, LL.D., D.Sc., F.R.S., M.Inst.C.E., on "Clutches" (Lecture II). Saturday, May 10, Professor H. S. Foxwell, F.B.A., on "Chapters in the Psychology of Industry" (Lecture II).

CONTRACTS.—Messrs. J. Samuel White and Co., Limited, East Cowes, Isle of Wight, have secured the contract to construct 12 steel barges of 200 tons capacity, for Messrs. William Cory and Son, shipowners, Cardiff, Newcastle-on-Tyne, Hull, Erith and South Shields.

BRITISH IRON AND STEEL PRODUCTION.—The Ministry of Munitions has issued statistics on pig-iron and steel production in the United Kingdom, from which we take the following figures as the March weekly average: Hematite pig-iron, output 61,000 tons, furnaces in blast 103. The figures for other classes of pig-iron were respectively, basic 51,000 tons and 81 furnaces; foundry, forge and other qualities 39,000 tons and 99 furnaces; alloys 5,000 tons and 12 furnaces. Total, 156,000 tons and 295 furnaces. The March weekly average output of steel ingots and castings was 174,000 tons.

APPOINTMENT OF MARINE SURVEYORS TO THE BOARD OF TRADE.—A memorandum has been issued by the Board of Trade stating that an examination for three appointments as engineer, two appointments as ship surveyor, and two appointments as nautical surveyor, will be held in London on Tuesday, June 24, and following days. One appointment as examiner of masters and mates will also be made through the examination for nautical surveyor, if a candidate is found qualified for this post. Any person desiring appointment must apply on a special application form, to be obtained from the Assistant Secretary, Marine Department, Board of Trade, Whitehall Gardens, S.W. 1. The list of candidates will be closed on Wednesday, May 7. Candidates must be within the following limits of age on the first day of the examination: Engineer and ship surveyor, 25 and 40; nautical surveyor, and examiner of masters and mates, 25 and 45. A candidate born on June 24 would be admitted on the twenty-fifth, but not on the fortieth or forty-fifth anniversary of his birth, as the case may be. Candidates must be natural-born British subjects, and the sons of parents both of whom were natural-born subjects or citizens of this or of an allied or associated country.

WELDING OF ALLOY STEELS.—Many alloy steels are considered practically non-weldable. To facilitate their welding, welding powders containing both iron filings, to supply a fusible medium, and borax, to prevent oxidation, are sometimes used. In the *Zeitschrift des Vereines Deutscher Ingenieure*, of February 19, 1919, Dr. N. Czako claims to weld various nickel, chrome and tungsten steels to a mild steel and also to a high-speed tool steel with the aid of a powder which is said to contain neither iron filings, nor borax, but which he does not further describe. He was anxious in the first instance to weld his high-speed steel (1) which contains 4 per cent. of chromium, 4 per cent. of molybdenum and 9 per cent. of tungsten; the other alloy steels contained (2) 12 per cent. of chromium, (3) 12 per cent. manganese, (4) 3 per cent. nickel, 0·5 per cent. chromium, (5) 1 per cent. chromium and 2 per cent. silicon; (6) was a 1·6 per cent. carbon steel and (7) a grey cast-iron. Photographic sections of his welds are reproduced in the journal mentioned. He welded No. 1 of his specimens to itself and all the others, in an ordinary coke fire; but his tests were merely made with plates 4 cm. by 2 cm., up to 1 cm. thick, which were welded to rods of the other material; in some cases the demarcation between the welded portion and the alloy was distinct, and not all his welds stood the hammer test.

YARROW'S SHALLOW-DRAUGHT GUNBOATS FOR THE TIGRIS.

(*For Description, see Page 570.*)

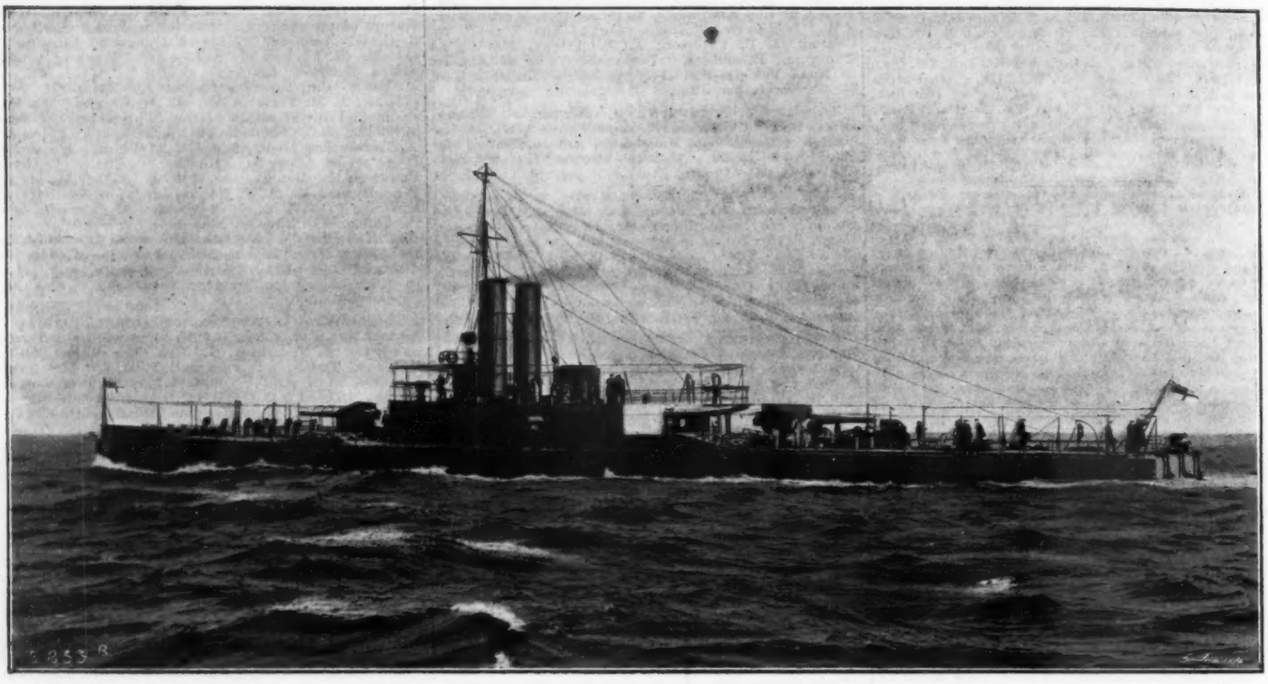


FIG. 1. LARGE GUNBOAT.

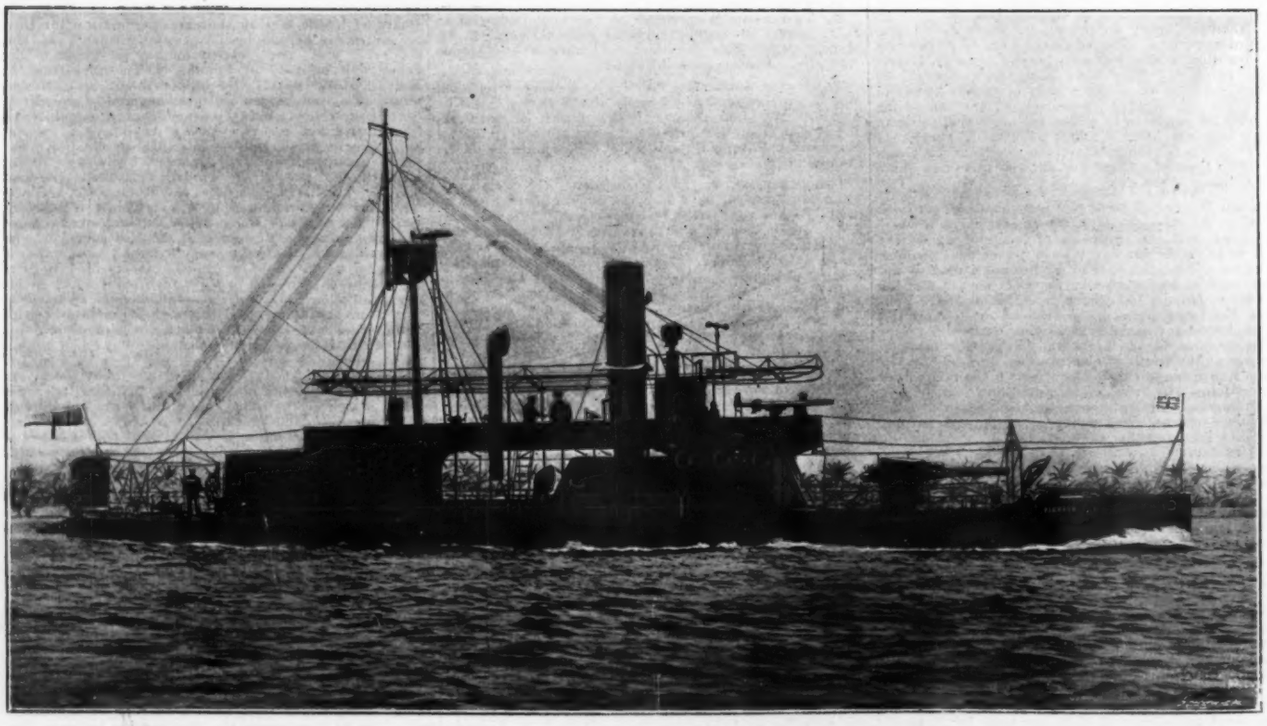
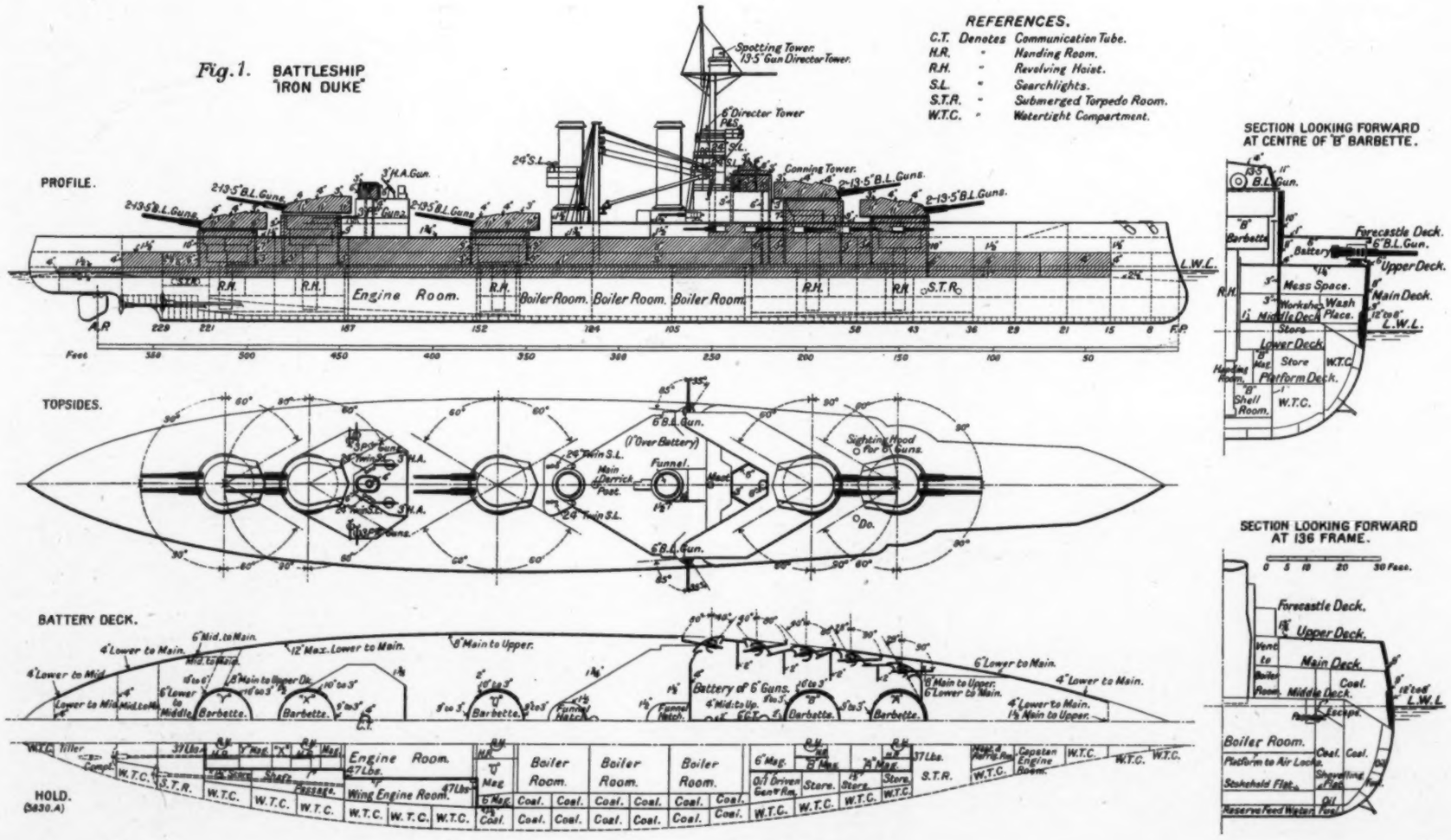


FIG. 2. SMALL GUNBOAT "FIREFLY."

SHIPS OF HIS MAJESTY'S NAVY ORDERED PRIOR TO THE WAR.

(*For Description, see Page* 581.)

Fig. 1. BATTLESHIP "IRON DUKE"



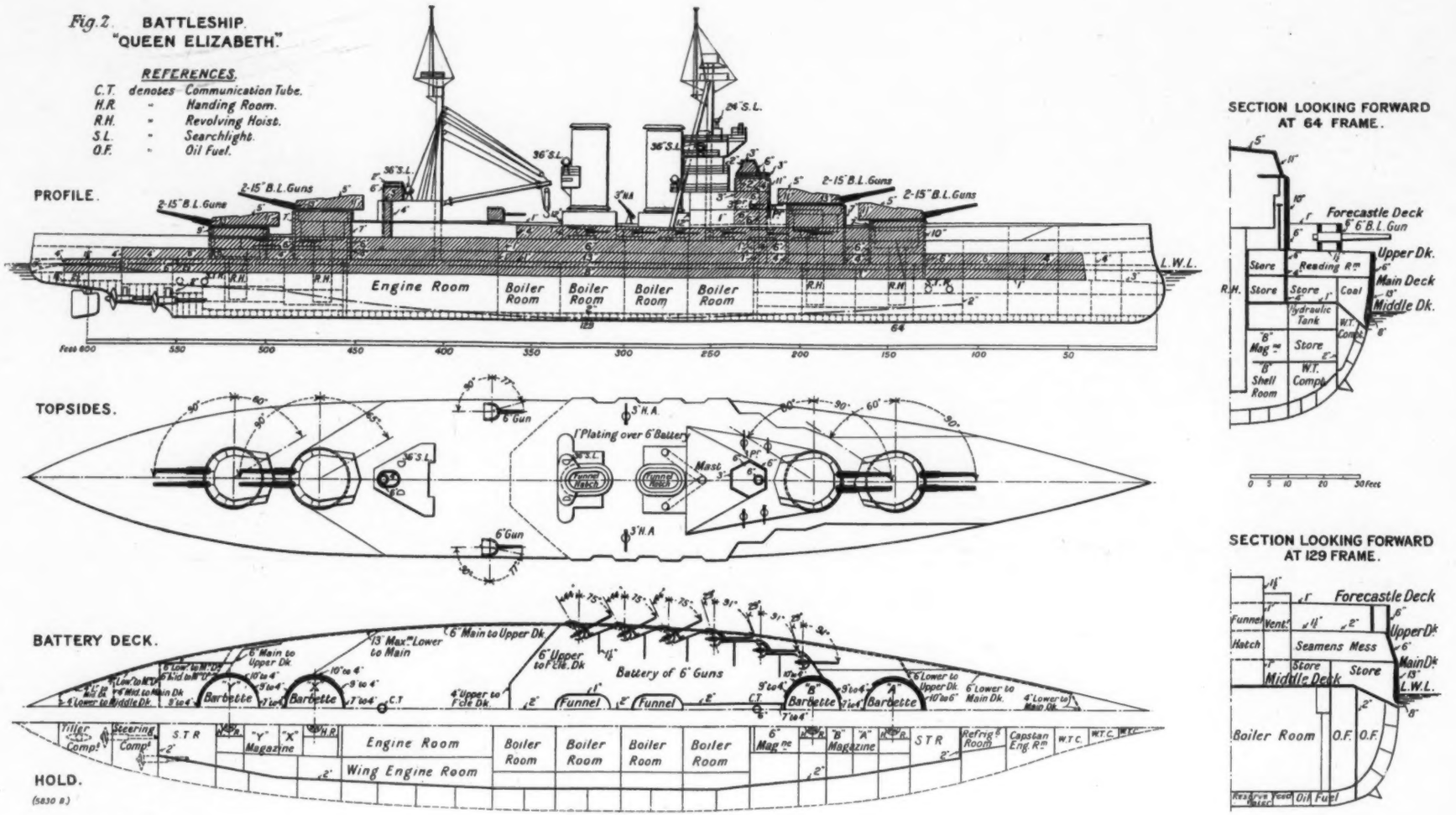
THE "IRON DUKE" CLASS OF BATTLESHIP, COMPRISING THE "BENBOW," "EMPEROR OF INDIA," "IRON DUKE" AND "MARLBOROUGH," COMPLETED IN 1914. LENGTH, 580 FT., BREADTH, 90 FT., DRAUGHT, 28 FT., DISPLACEMENT, 25,000 TONS; SHAFT HORSE-POWER OF TURBINE MACHINERY, 29,000; SPEED OF SHIP, 21·25 KNOTS; ARMOUR ON BELT, 12 IN., ON GUN POSITIONS, 11 IN.; MAIN ARMAMENT, TEN 13·5-IN., TWELVE 6-IN., TWO 3-IN. AND FOUR 3-PDR. GUNS, WITH FOUR 21-INCH. SUBMERGED TORPEDO TUBES.

(*To face page* 582.)

SHIPS OF HIS MAJESTY'S NAVY ORDERED PRIOR TO THE WAR.

(*For Description, see Page* 581.)

Fig. 2. BATTLESHIP "QUEEN ELIZABETH."



SECTION LOOKING FORWARD AT 64 FRAME.

SECTION LOOKING FORWARD AT 129 FRAME.

THE "QUEEN ELIZABETH" CLASS OF BATTLESHIP, COMPRISING THE "QUEEN ELIZABETH," "WARSPITE," "BARHAM," "VALIANT," AND "MALAYA," COMPLETED IN 1915–16. LENGTH, 600 FT., BREADTH, 90 FT. 6 IN., DRAUGHT, 28 FT. 9 IN., DISPLACEMENT, 27,500 TONS; SHAFT HORSE-POWER OF TURBINE MACHINERY, 56,000, SPEED OF SHIP, 25 KNOTS; ARMOUR ON BELT, 13 IN., ON GUN POSITIONS, 11 IN.; MAIN ARMAMENT, EIGHT 15-IN., FOURTEEN 6-IN., TWO 3-IN., FOUR 3-PDR. GUNS, WITH FOUR 21-IN. SUBMERGED TORPEDO TUBES.

ELECTRIC LOCOMOTIVES FOR THE SWISS FEDERAL RAILWAYS.

CONSTRUCTED BY MESSRS. BROWN, BOVERI AND CO., ENGINEERS, BADEN, SWITZERLAND.

(*For Description, see Page* 562)

Fig. 1.

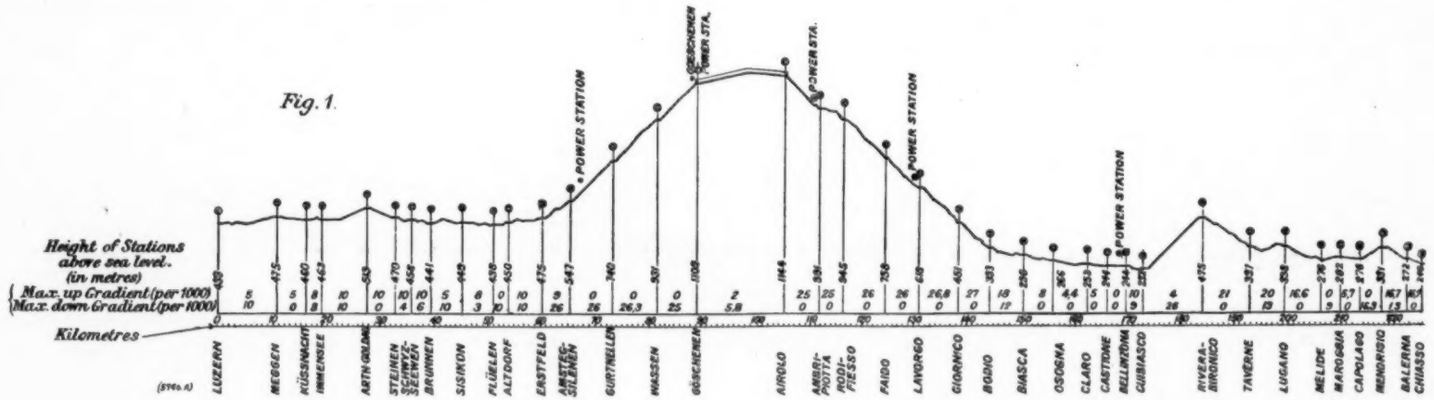


Fig. 2.

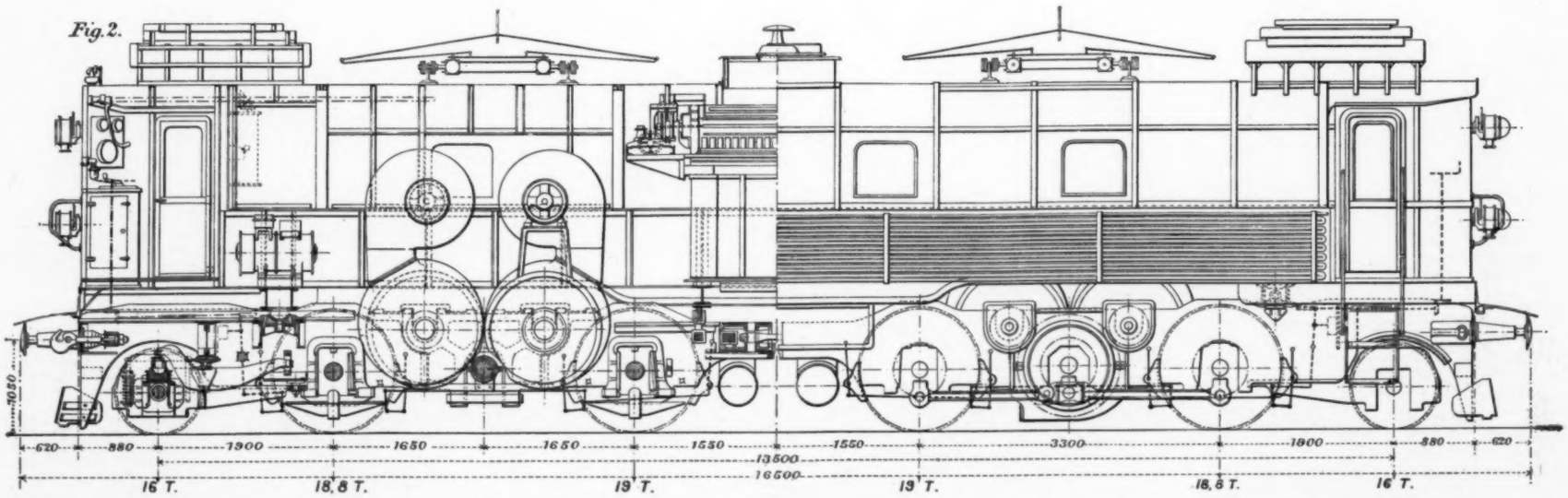
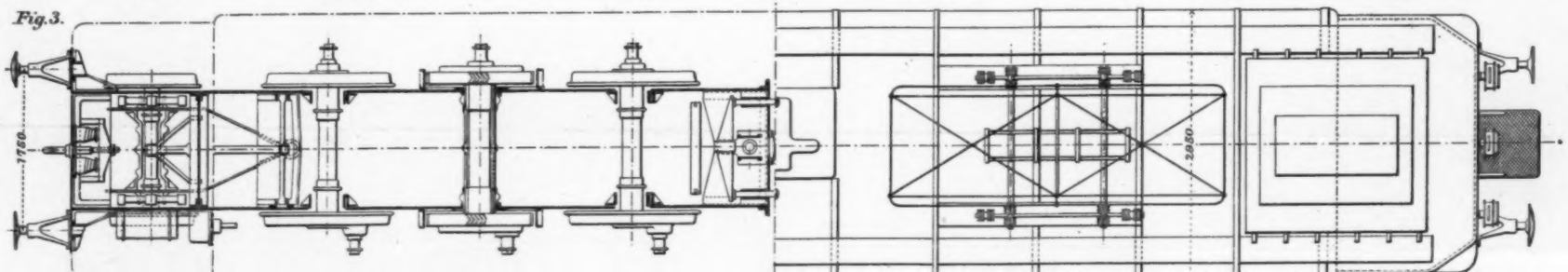
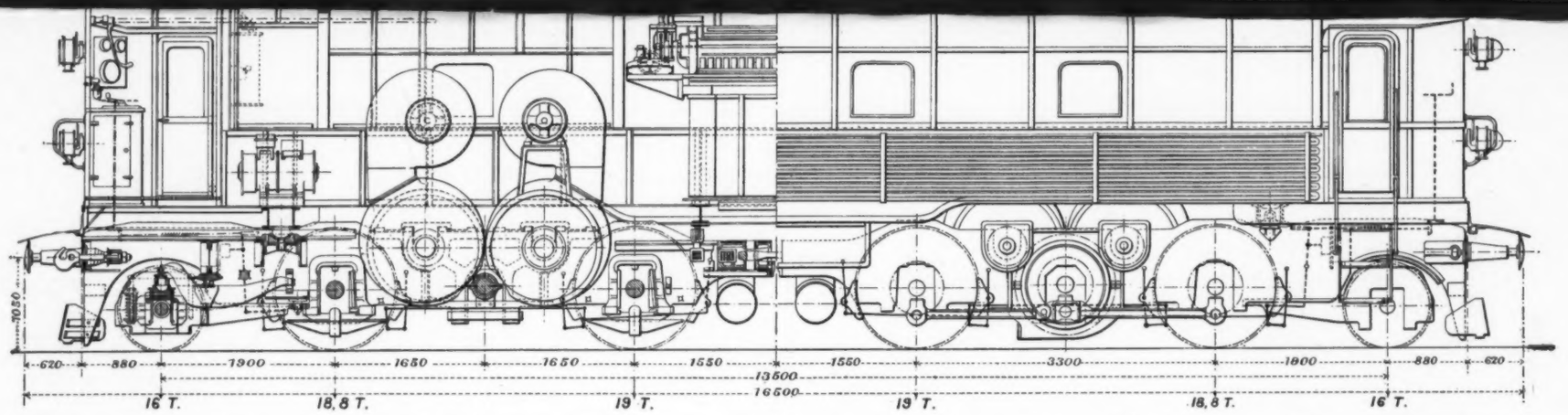


Fig. 3.




10150
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16 T.
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19 T.
18,8 T.
16 T.

Fig.3.

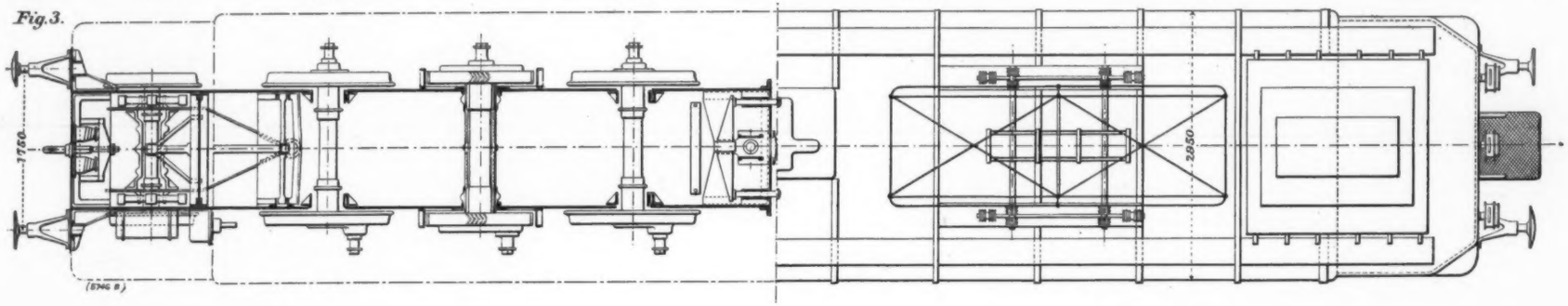
1750
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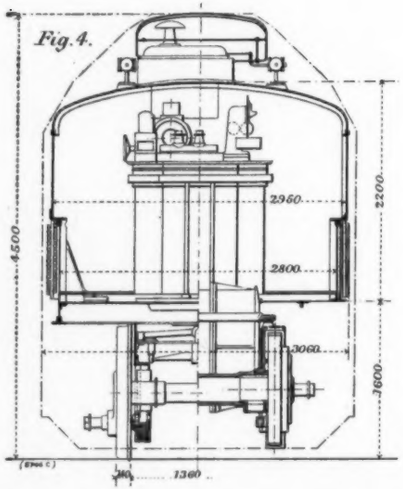
Fig. 4.



EXPRESS LOCOMOTIVE.

(FIGS. 2 TO 4.)

Current, single phase	15,000 volts
Periodicity	16⅔ cycles per sec.
Four motors of	540 H.P. each
Gauge	4 ft. 8½ in.
Diameter of driving wheels	4 ft. 5½ in.
Diameter of leading wheels	3 ft. 6⅛ in.
Weight of electrical part	49·6 tons
Weight of mechanical part	58 tons
Total	107·6 tons
Maximum speed	46½ miles per hour

GOODS LOCOMOTIVE.

(FIGS. 5 TO 7.)

Current, single phase	15,000 volts
Periodicity	16⅔ cycles per sec.
Four motors of	550 H.P. each
Gauge	4 ft. 8½ in.
Diameter of driving wheels	4 ft. 5½ in.
Diameter of leading wheels	2 ft. 9½ in.
Weight of electrical part	51·2 tons
Weight of mechanical part	69·8 tons
Total	121·0 tons
Maximum speed	40 miles per hour

Fig. 5.

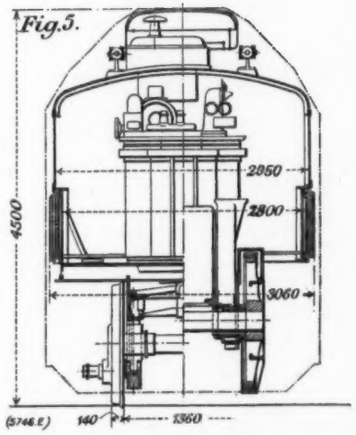


Fig. 6.

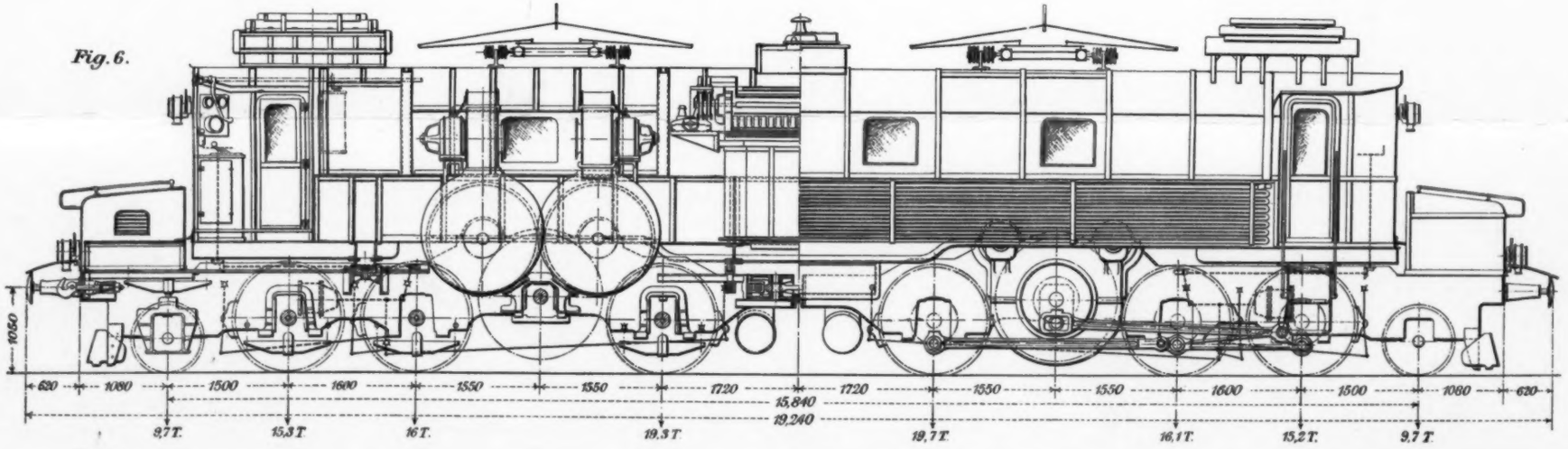
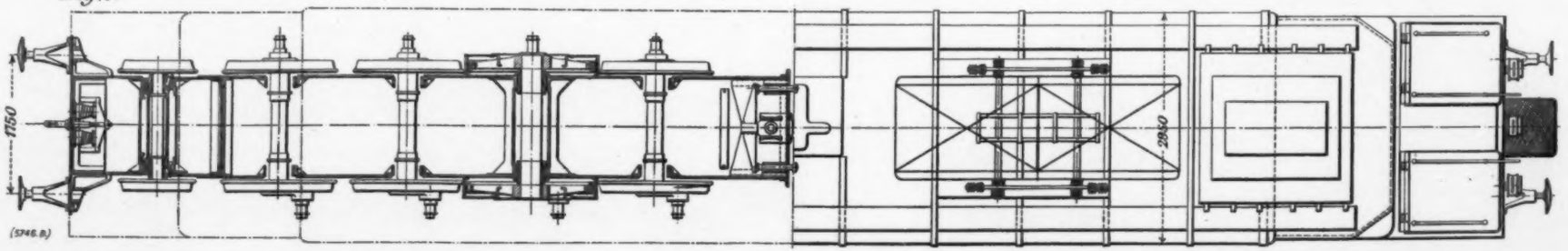


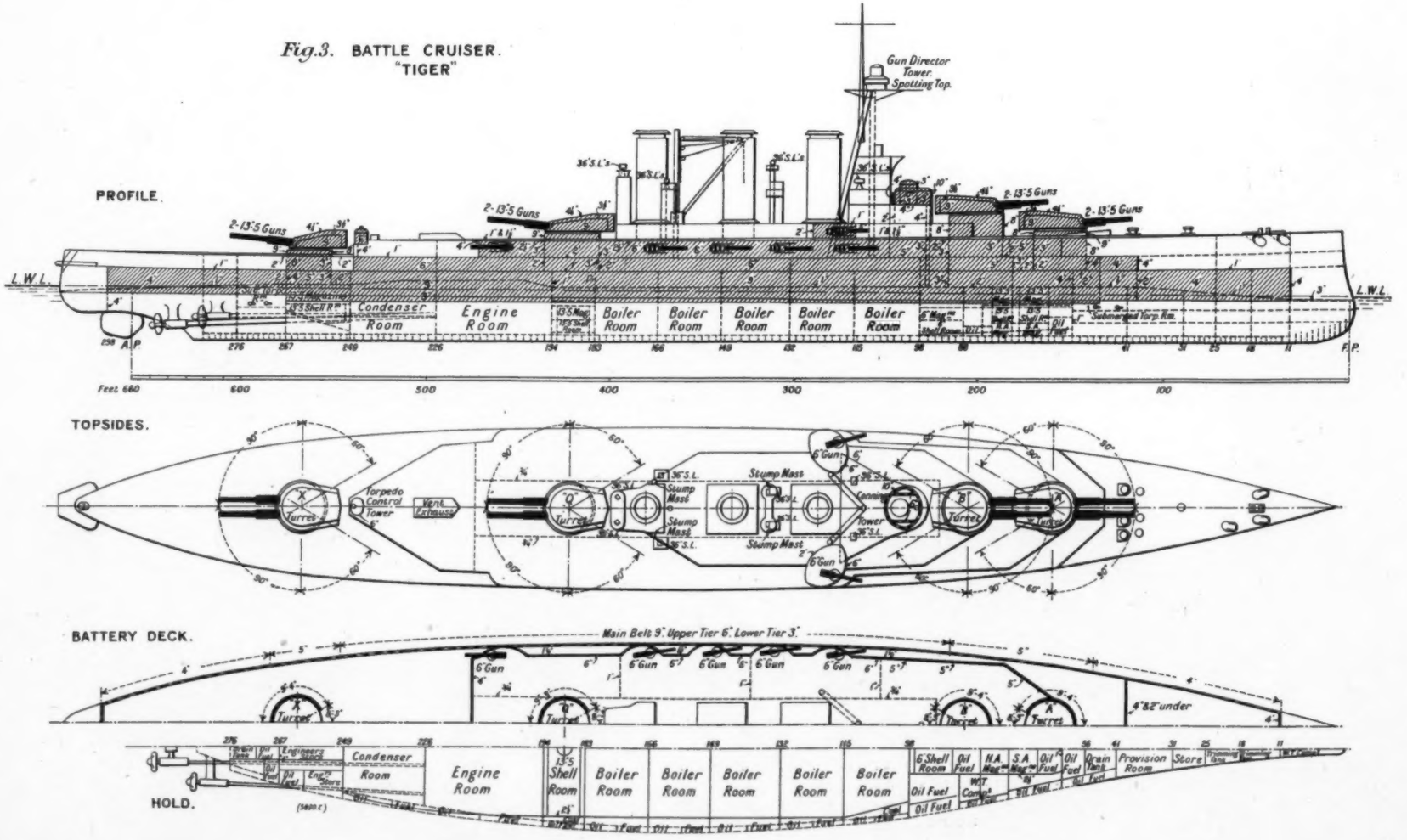
Fig. 7.



SHIPS OF HIS MAJESTY'S NAVY ORDERED PRIOR TO THE WAR.

(*For Description, see Page* 581.)

Fig.3. BATTLE CRUISER. "TIGER"

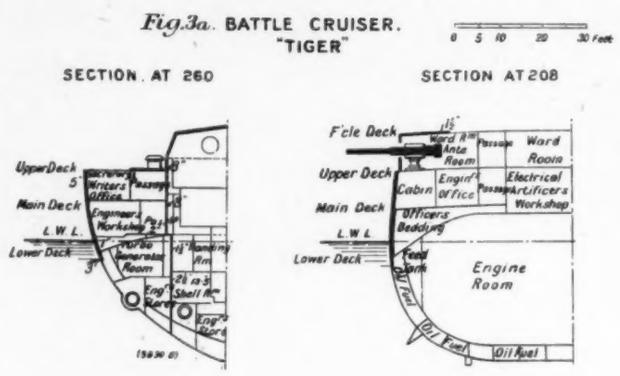


H.M. Battle Cruiser "Tiger," completed in 1914. Length, 660 Ft., Breadth, 90 Ft. 6 in., Draught, 28 Ft. 3 In., Displacement, 28,500 Tons; Shaft Horse-Power of Turbine Machinery, 85,000, Speed of Ship, 28 Knots; Armour on Belt, 9 In., on Gun Positions, 9 In. Main Armament, Eight 13·5-In., Twelve 6-In., Two 3-In., and Four 3-Pdr. Guns, with Four 21-in. Submerged Torpedo Tubes (for Cross Section of H.M.S. "Tiger," see Fig. 3A, on Plate XLVI).

SHIPS OF HIS MAJESTY'S NAVY ORDERED PRIOR TO THE WAR.

(*For Description, see Page* 581.)

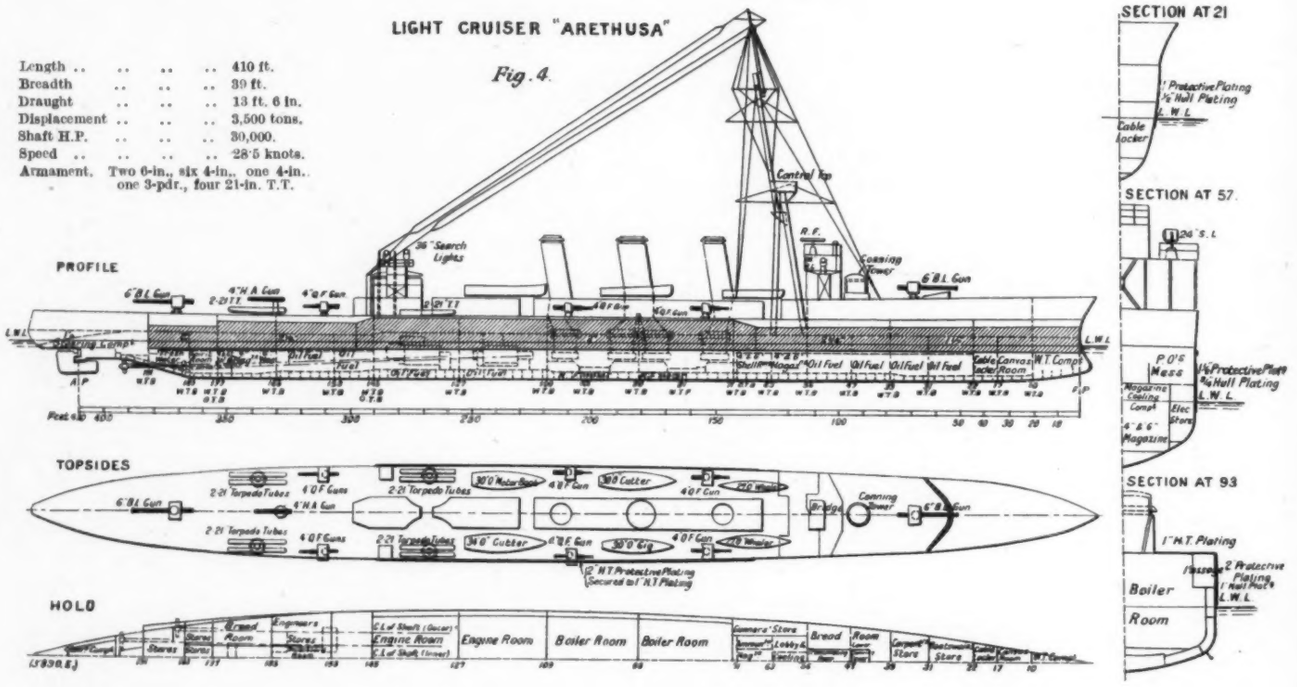
Fig.3a. BATTLE CRUISER. "TIGER"



LIGHT CRUISER "ARETHUSA"

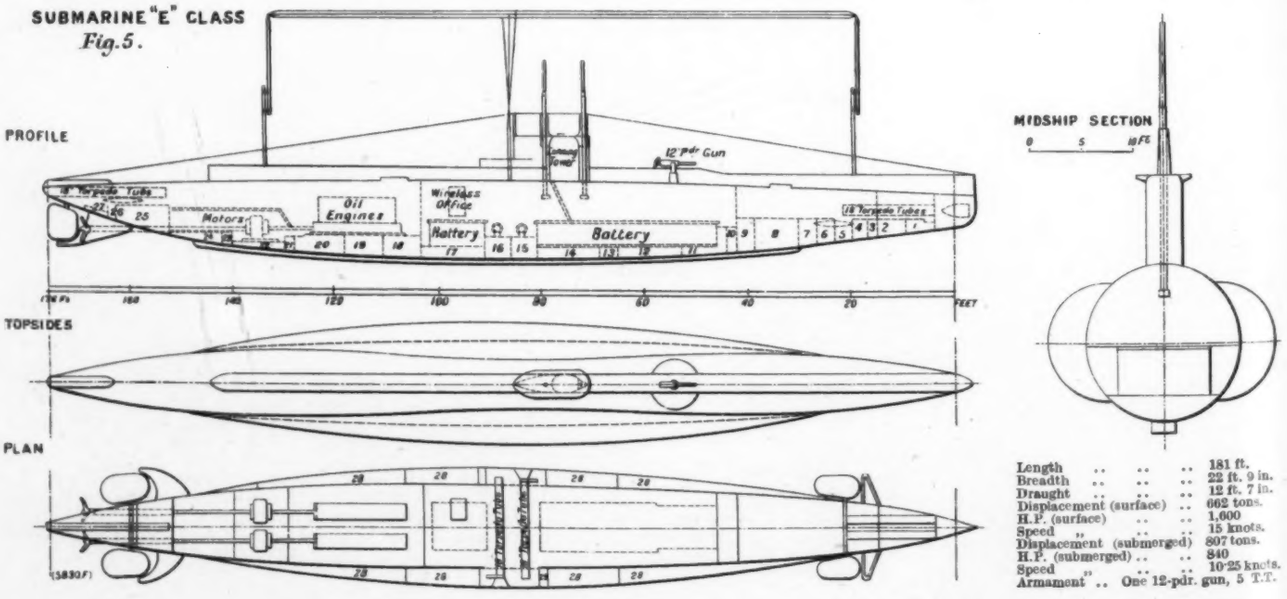
Fig.4.

Length	410 ft.
Breadth	39 ft.
Draught	13 ft. 6 in.
Displacement	3,500 tons.
Shaft H.P.	30,000.
Speed	28·5 knots.
Armament.	Two 6-in., six 4-in., one 4-in. one 3-pdr., four 21-in. T.T.



SUBMARINE "E" CLASS

Fig.5.



Length	181 ft.
Breadth	22 ft. 9 in.
Draught	12 ft. 7 in.
Displacement (surface)	662 tons.
H.P. (surface)	1,600
Speed ,,	15 knots.
Displacement (submerged)	807 tons.
H.P. (submerged)	840
Speed ,,	10·25 knots.
Armament	One 12-pdr. gun, 5 T.T.

(*To face page* 583.)

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ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2½ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3863 and 8598 GERRARD.

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With One Two-Page Plate of the ELECTRIC LOCOMOTIVES FOR THE SWISS FEDERAL RAILWAYS, and Four One-Page Plates of the SHIPS OF HIS MAJESTY'S NAVY ORDERED PRIOR TO THE WAR.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 571.

ENGINEERING.

FRIDAY, MAY 2, 1919.

ROAD LOCOMOTIVES AND HEAVY MOTOR CARS.

THE Report of the Departmental Committee appointed by the Local Government Board in March, 1915, to consider the law and regulations relating to the construction and use of road locomotives and heavy motor cars in Great Britain, has just been published. The committee was appointed on account of complaints made by road authorities as to damage caused to roads by heavy mechanically-propelled traffic, and its object was to examine into these complaints and to advise as to the steps necessary to be taken with regard to the damage. The length of time that has elapsed between the appointment of the committee and the presentation of its report is, of course, due to conditions arising out of the war, so that no criticism can reasonably be raised on that score. The committee have examined a large number of witnesses representing various road authorities, makers and users of road locomotives and heavy motor cars, and also representatives of agricultural interests. The views of all parties seem to have been carefully considered, and the suggested alterations to the law and regulations, although by no means drastic, appear likely to reduce road wear without imposing undue restrictions on the industries concerned.

That widespread and extensive damage has been done by the class of traffic being considered appears to have been established without doubt by the evidence before the committee, but this damage is largely due to the traffic using roads quite unsuitable for it. In the case of roads paved with setts, wood, or asphalte, on concrete foundations, the evidence seems to indicate that such damage as occurs is caused mainly by iron and steel-tyred traffic. Rubber-tyred traffic, even when travelling at high speeds on such roads, appears to have no serious effect provided that the surface is kept reasonably smooth and level. As regards the modern method of road construction in which bituminous materials are used as a binder or matrix, the evidence is not so conclusive, but there appears to be no doubt that such roads, if properly constructed and maintained, are capable of carrying a considerable amount of heavy traffic without damage. With the commoner form of water-bound macadam road the committee are of the opinion that the damage is mainly due to rubber-tyred traffic.

The report deals first with road locomotives, considering separately the questions of weight, construction and speed. With regard to the first point the committee do not consider it necessary to reduce the weight of traction engines from the existing maximum of 14 tons, and, in the case of engines fitted with Boulton wood block driving wheels, they suggest that the maximum should be increased to 18 tons. Weight, however, is to be more clearly defined, and the suggestion is that the term should include all parts necessary to, or ordinarily used with, the engine as employed on the road, excepting water, fuel and loose tools and equipment. Licensing authorities, it is thought, should ascertain the correct weight by actually weighing the engine. One recommendation with regard to the wheels of road locomotives is that the distinction made by the Act of 1878 between a locomotive drawing a wagon and one not so employed should be abolished. Another is that the width of the tyre of each wheel, whether steering or driving, should be at least 5 in., and the width of tyres for driving wheels should be such as to comply with Section 28 (Subsection 2) of the 1878 Act. If bands are used on steering wheels their widths must not be less than 5 in. The committee, although they have been satisfied that serious damage to roads has been caused by cross-barred driving wheels, do not consider it possible to prohibit their use without seriously reducing the hauling capacity of traction engines, or restricting the use of agricultural locomotives. To diminish the damage as much as possible, the cross-bars, it is suggested, should be arranged so that the aggregate extent of the cross-bar (or bars), in the course of a straight line drawn horizontally across the circumference of the wheel, should be nowhere less than half the width of the tyre. They also consider that the use of cross-bars should be prohibited on wheels less than 4½ ft. in diameter. The committee consider it desirable to require road locomotives to be mounted on springs, except in the cases of road rollers and ploughing engines, but it may be noted that existing locomotives are exempted from all the above-mentioned recommendations.

The existing provisions with regard to wagons drawn by locomotives are admittedly antiquated and unsatisfactory, and a number of alterations to these are recommended. These recommendations, which we cannot spare the space necessary to refer to in detail, relate to the marking of unladen weights, forms and widths of tyres, and diameters of wheels. Springs are not insisted upon, but to encourage their use as much as possible it is proposed to allow additional weights on spring-mounted wagons, or to permit the use of smaller wheels for a given loading, when springs are employed. It is also recommended that a highway authority should be notified in advance of the passage over a road in its area of a traction engine hauling a wagon carrying a single article exceeding 16 tons in weight. No alteration is proposed in the existing speed limit for road locomotives of 4 m.p.h. in the country, but in towns it is thought that undue congestion is caused by the present speed limit of 2 m.p.h. The committee therefore recommend that the latter be increased to 3 m.p.h.

Owing to the many different types of vehicles which come under the heading of heavy motor cars, and to the great variety of uses to which they are put, the framing of regulations for their construction and use is naturally more difficult than is the case with road locomotives. The enormous development in the use of such vehicles, however, renders a solution of the problems involved imperative, and, as the committee fully realise, the convenience of a very large section of the general public is greatly affected by the decisions made. The committee have, of necessity, considered the question mainly from the point of view of damage to roads, and we share with them the hope that the financial burdens will ultimately fall upon the right shoulders. We also agree with their view that the adjustment of this burden is the crux of the whole question of mechanically-propelled traffic.

Heavy motor cars are dealt with in a manner similar to that adopted for road locomotives, that is to say the questions of weight, construction and speed are treated separately. With regard to weight, it is proposed to increase the maximum allowed for the motor car alone, from 5 tons to 6 tons unladen, and the combined unladen weight of car and trailer from 6½ tons to 8 tons. The unladen weight is to include all parts necessary to, or ordinarily used with, the car when working on the road, but is not to include water, fuel or accumulators (other than boilers) used for propulsion, or loose tools or equipment. It is not considered necessary to alter the existing maximum laden weight of 12 tons for the car, or 8 tons for any axle of the car, or 4 tons for any axle of the trailer, but some measures are proposed for securing stricter compliance with limitations on weight. With regard to the construction of wheels the committee recommend that in the case of wheels fitted with iron, steel or other hard tyres, the minimum diameter should be raised from 2 ft. to 2 ft. 9 in., and that, for axle weights exceeding 4 tons, wheels of the following diameters should be used:—

	ft.	in.
Axle weights exceeding 4 tons but not exceeding 5 tons	3	3
Axle weights exceeding 5 tons but not exceeding 6 tons	3	6
Axle weights exceeding 6 tons	4	0

The edges of the tyres of such wheels should be rounded and not bevelled, but in other respects the existing regulations should not be altered. For rubber-tyred wheels the proposed minimum diameter is 2 ft. 6 in., but no regulation is proposed with regard to the size or shape of the tyre itself. Neither is it considered necessary to prescribe a scale of minimum diameters proportionate to axle weights in the case of wheels fitted with rubber tyres.

There are, at present, no regulations restricting the overall length of vehicles, length of wheel base, or amount of overhang of the body behind the driving axle, and, as a consequence of this, the tendency of makers has been to bring the rear axle as far forward as possible. This feature, although giving a better drive, has the effect, in the opinion of the committee, of damaging the roads to a considerable extent. It, of course, throws an undue proportion of the total weight of the vehicle upon the driving axle, and is partly responsible for the contraventions of the existing regulations as to axle weight which have occurred in the past. It also increases the swinging motion of the rear of the vehicle, and so augments the force of the impact on the road surface when the latter is at all uneven. To diminish this source of trouble it is proposed to limit the maximum overall length of a heavy motor car to 26 ft., and to fix the amount of overhang behind the rear axle to a quantity not exceeding seven twenty-fourths of the overall length of the car. It is not proposed to make any definite regulation as to the length of wheel base. London motor omnibuses, the committee think, should be required to conform to the above-mentioned rule with regard to overhang, even if the necessary structural alterations involve some increase in weight, but the amended regulations with regard to wheel diameters, length of vehicle, and amount of overhang, will not be made to apply to any class of heavy motor car in use at the time the new regulations come into force; neither is it proposed to reduce the load which such cars would otherwise be permitted to carry. The committee also propose to exempt motor rollers from compliance with any requirement as to the construction of wheels or tyres.

With regard to the use of trailers it is proposed to retain the existing law, which permits the use of only one trailer behind a heavy motor car, and if more than one trailer is used the motor tractor is to be treated, in law, as a locomotive. It is proposed to limit the aggregate of the marked axle weights of a trailer to 8 tons, and to raise the minimum diameters of wheels of trailers exceeding 1 ton in weight unladen from 2 ft., as at present, to 2 ft. 6 in. when iron or steel tyres are employed; the edges of the tyres are to be rounded. No minimum diameter is to be fixed for trailer wheels with rubber tyres. It is not proposed to permit trailers carrying passengers or luggage to be drawn by passenger-carrying vehicles.

The question of speed limits for heavy motor traffic has been gone into very fully by the committee. Proposals were made by representatives of the Metropolitan Borough Councils to reduce the speeds of motor omnibuses from 12 m.p.h. to 10 m.p.h., and of other rubber-tyred traffic from 8 m.p.h. and 12 m.p.h. to 5 m.p.h. and 8 m.p.h. respectively. The London General Omnibus Company, however, wished the limit for motor 'buses to be raised to 16 m.p.h. These proposals, and others made on behalf of motor users, were very carefully considered, and as a result of their deliberations, the committee recommend that the present regulations be retained subject to the amendments that the speed of heavy motor cars with iron or steel tyres shall in no case exceed 5 m.p.h., and that, when drawing a trailer, the maximum speed shall be raised from 5 m.p.h. to 8 m.p.h., provided that both motor and trailer are fitted with rubber tyres.

The report also deals with the restriction of heavy traffic on unsuitable roads, recommending that motor omnibus, and similar passenger traffic, should be brought under special regulations in this respect. It is also proposed to confer powers on the Local Government Board, and the road authorities, to regulate through traffic of heavy motor vehicles so as to ensure, as far as possible, that such traffic shall use roads suitably constructed to carry it. County councils, it is considered, should be given power to regulate traffic on a road under repair, and to divert the traffic on to another road. The committee has also considered a number of special questions, and it may be of interest to mention their recommendations in respect to some of them. In place of the existing provisions regarding the emission of smoke, or visible vapour, from locomotives or motor cars on public highways, it is proposed to make it an offence to cause, or permit, the emission of such smoke or vapour in such quantity as to be a nuisance or danger to the public. The by-law requiring the provision of means of communication between the rear wagon of a train of wagons and the locomotive driver is to be made a statutory requirement, and heavy motor cars will be required to carry a mirror to enable the driver to see overtaking traffic. Motor users will also be glad to note that the committee recommend that "the existing law should be amended so as to provide more effective measures for securing the strengthening and improvement of bridges which do not meet the requirements of heavy self-propelled traffic, and to ensure the removal, and prevent the imposition, of unnecessary restrictions upon the use of bridges by such traffic." It is also suggested that public funds should be made available to encourage the design and construction of vehicles calculated to cause less damage to roads. Facilities would be given for trials and demonstrations of such vehicles to be made on public roads, although the vehicles could not be ordinarily employed without breach of the law.

The proposals made in the report* dealt with have a special interest at the present time, in view of the inclusion of road transport in the Ways and Communications Bill now under consideration. They are likely to be passed into law, and the evident desire of the committee to draw a just balance between interests which are naturally rather conflicting entitles their recommendations to careful consideration.

THE EXTRACTION OF HELIUM FROM NATURAL GAS.

SOME weeks ago news came from New York that Dr. Cottrell had been awarded the Perkin medal of the Society of Chemical Industry for working out a new process of helium extraction. The news was substantially correct, but we see from information which has since become available, that the award was really made for the success which Dr. Cottrell has achieved in clearing factory gases from obnoxious dust and fumes. That is his own particular line of research. In the helium extraction he is associated with other investigators, and the mention of this investigation was due to the fact that, in returning thanks for the honour conferred upon him, he spoke upon the helium extraction, instead of summarising the researches for which he had been distinguished.

Since the researches on new ways of preparing helium and its utilisation, especially for aircraft, originated in this country, however, we will first notice this work, though little can be said about it at present. Various proposals for the substitution of helium for hydrogen in aircraft seem to have been made both on the side of the Allies and on the enemy side. The first practical suggestion to this effect was probably due to Sir Richard Threlfull, who pointed to natural gas as a source of helium supply; with the assistance of the Admiralty he was able to make calculations as to the work of the isolation and transportation of helium, and these calculations showed the feasibility of the scheme. The Board of Invention and Research then in 1915 invited Professor J. C. McLennan of the University of Toronto, previously known best in connection with his researches on radioactivity and on single-line spectra, to report upon the helium sources of the British Empire and to enter upon an experimental research on semi-commercial lines. Assisted by his colleagues, Messrs. J. F. Satterly, E. F. Burbon, H. F. Dawes, J. Patterson and J. McTaggart, and co-operating with the Air Liquide Company, Professor McLennan worked out the technical details of helium production and of its re-purification after having done service in aircraft and having thus become contaminated with air. A technical station was erected also for the liquefaction of helium, and methods were worked out for testing the purity of the gas; since helium and the other rare gases are most inert, different methods had to be used, balance and spectroscopic methods proving most suitable. The permeability of falvin to helium was also studied. It is further noteworthy that Professor McLennan inquired into the utilisation of helium in the lamp industry, for charging lamp bulbs, and in thermoionic valves that have in recent years become reliable technical apparatus. By the time the Armistice was concluded, Canada was ready to supply helium for aircraft. That question is no longer urgent now; but the utility of the expensive researches is little affected by this circumstance. In summer 1917, the United States took the matter up, and we turn to their share in the work according to the fuller information given by Dr. Cottrell.

Mr. Frederick Gardner Cottrell is a San Francisco man. Born in 1877, he studied at the University of California, where he took his B.Sc., and at Leipzig; he returned to his old university in 1902 as instructor, and has since 1911 been connected with the United States Bureau of Mines, first as chemist, lately as chief metallurgist. His experiments on the precipitation of sulphuric acid fumes by high-tension electric discharges had, by 1906, been crowned by a measure of success. But they would hardly have been persisted in if the Selby Smelter Company had not experienced serious trouble from a tunnel of the Southern Pacific Railroad becoming choked with the works' fumes when the wind was blowing in a certain direction; some means had to be found of stopping this nuisance. In connection with these experiments the Research Corporation was established, and Dr. Cottrell referred in his speech also to this corporation and to the public administration of patent rights. His main subject was, however, the isolation of helium, a war problem. In 1915 the British Government consulted the late Sir William Ramsay as to whether it would be possible to fill balloons with helium instead of with hydrogen, and whether sufficient amounts of helium could be supplied for the purpose. Helium is the lightest gas next to hydrogen, having twice the density and 92 per cent. of the buoyancy of hydrogen; the advantages of helium are that it is not inflammable, and that airships or balloons filled with helium would hence not be exposed to explosions by the flashes from the motors, by lightning or other electric sparks, or when attacked; the rate of diffusion of helium through balloon fabrics is moreover only half as large as with hydrogen. Ramsay experimented with the discharge from a natural gas blower; as his supply was very limited, however, he appealed to scientists in Canada and in the United States. When America joined in the war, the question was energetically pushed; in July, 1917, the Aircraft Board allowed 100,000 dols. for the research, and the Admiralty soon afterwards made a further grant of five times that sum, when a Commission from the British Admiralty went over to America. Dr. Cottrell had long been interested in the liquefaction and isolation of gases; and the Bureau of Mines took the matter up with special regard to the patented processes of E. A. W. Jeffries and F. E. Norton. Meanwhile the Linde Air Products Company and the Air Reduction Company (process of Georges Claude, of Paris) had offered their services, and these companies erected plants at North Fort Worth, in Texas, each for 7,000 cub. ft. of helium per day. The helium source to be worked was natural gas, which was supplied through a pipe line from Petrolia in Texas, by the Lone Star Company; the gas in question contains about 0·9 per cent. of helium. By April, 1918, the Linde plant, which had cost

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300,000 dols., started supplying a gas of 25 per cent. of helium; by September last they produced 7,750 cub. ft. of 67 per cent. daily, and the purity was soon raised to 93 per cent. The Claude plant—we rely on the statements made by Dr. Cottrell—was completed a few weeks after the Linde plant, at half the cost of the earlier installation, but it was still considerably behind the Linde works.

The construction of the Jeffries–Norton plant of the Bureau of Mines, at Petrolia, was completed about the middle of October last; the actual production of helium, however, had not been started at the date of Mr. Cottrell's remarks. Much anxiety had been felt about the new features of this process, the multitubular heat interchanger and the large expansion engines; so far they have answered very well, however, although any changes and adjustments in this plant, which was several times larger than the others, required much time and work. At the time when the armistice was signed, the first shipment of 147,000 cub. ft. of 95 per cent. helium was ready for shipment to Europe in the docks; in what condition that helium was preserved, Dr. Cottrell did not say. The Army and Navy had now entered upon a larger joint programme, for the production of 50,000 cub. ft. of helium per day with the aid of a new pipe line and further units, for the construction of which 5,000,000 dols. had been set aside.

Dr. Cottrell gave hardly any technical information, but his remarks on the theory of the processes are of interest. We have, in the first instance, to distinguish between the production of a liquid, as an ultimate product, and the utilisation of liquefaction and re-evaporation as a mere step in a separation process, where the ultimate products desired are still gases at ordinary temperature. In the former case, a very considerable expenditure of work is represented by the "refrigerative properties" of the liquid delivered. In the latter case, where the liquid is not drawn off from the apparatus, but remains constant in amount, the part continually evaporating serves to condense nearly an equivalent amount of the incoming gases; further, the cold gases furnished by this evaporation take up heat from the incoming fresh gas and cool it, while they themselves are returning to their original temperature.

Dr. Cottrell bases his consideration on the "ideal equal pressure process" of the liquefaction and re-evaporation of a single gas. Imagine, he said, a U-tube of such a kind that the two inner walls of the limbs are united—in other words a single tube, divided into two tubes A and C by a vertical partition not going quite down to the bottom, but branching above into two distinct tubes; the bottom B of the U-tube can be cooled by an extraneous source. The ideal conditions would consist in a perfect heat exchange horizontally between the two limbs A and C and in perfect heat insulation lengthwise along each of the limbs and from the surroundings. The whole system, apart from the upper branch tubes, is enclosed within a heat-tight chamber. If the conditions outlined be fulfilled, and gas is slowly passed down tube A, a certain amount of liquid will be condensed in the bottom of the U, and a uniform gradient of temperature will be established along the limbs. If now the source of cooling be removed, but gas still be fed into A, the gas would progressively cool in A, liquefy at B at the bottom of A, re-evaporate at B_1, in the bottom of C, and become warm again in passing up C. With a single gas the slightest difference in pressure between A and C should be sufficient to perpetuate the process. Any heat leakage would not represent a loss of energy itself, but of its availability for the purpose desired. When now we have, instead of one gas, a mixture of gases, the constituents will in general liquefy and re-evaporate with different degrees of ease, tending to set up temperature differences between adjacent parts of A and C, and we shall thus require further expenditure of work to operate the cycle. The problem is to provide for just enough refrigeration, at the proper temperature and places, to cover these losses, after reducing them as much as possible by the design and the insulation of the apparatus.

The three systems in operation now differ most strikingly as to the method of producing refrigeration. In the Linde system the gas mixture is pumped into A at high pressure (up to 3,000 lb. per square inch), allowed to expand through a regulating throttle to a lower pressure at B_1, and returns up C. The refrigeration is credited to the Joule–Thomson effect: a highly-compressed gas has (usually) a lower specific heat than the same gas at lower pressure; thus a given weight of gas passing down A under high pressure in falling from one temperature to another will give up fewer calories of heat than the same weight of gas coming up C will absorb between the same two temperatures. More heat will therefore be carried out of the system by the issuing gas than is brought in by the incoming gas, and refrigeration will take place. Now these differences of specific heat only become important at high pressures and are practically wasted at the throttle, so far as useful mechanical effect is concerned. Hence the Linde system is inefficient from the standpoint of power consumption. It has the merit, however, of extreme simplicity and freedom of moving parts. As cooling proceeds, liquid forms at B, and the separation of the constituent gases is effected by developing C into a column still for rectification.

In the Claude system another principle is introduced. If some sort of expansion engine could be substituted for the free-expansion throttle, and the work of this engine be expended outside the heat-tight chamber, greater refrigerative effect would be realised even if all the mechanical work so produced were allowed to go to waste; for in its mere production it would already have extracted an equivalent amount of heat from this room. Such engines must work at very low temperatures; grave troubles as to lubrication, brittle valves, stoppage of passages by frozen impurities, &c., had therefore to be met, and Claude was the first to overcome these difficulties commercially. By the use of one expansion engine Claude reduced the initial gas pressure down to 400 lb. per square inch and less; at these low pressures, however, the specific heat change of the Linde machine practically vanishes, so that the principle of Claude is not the same as in the Linde machine. As Claude has only one engine at moderate pressure, he has to locate the engine's gas intake at a level in his interchanger sufficiently low so that the exhaust will reach the lowest temperature desired in the system and still be able to absorb an appreciable amount of heat at this temperature. With the one engine taking its gas from the A limb only part of the gas can be expanded through the engine, for liquefaction must not take place in the cylinders; the remainder of the gas must be retained in the U and cooled down and liquefied by heat exchange with the expanded gas returning; in Dr. Cottrell's diagrams (the diagrams were taken from a paper by Norton and Burrell) this path of the gas was indicated by a spiral encircling both the limbs of the U, the gas finally joining C through the throttle to undergo further distillation in C as explained.

Now the novel points in which Jeffries and Norton differ from Claude, are the following: (1) Instead of one engine they have three, taking their gas respectively from a point low down on C, a point higher up and a third point higher up again; each engine works through a different temperature range; (2) the pressure in C is only a little below that in A, enough to allow for proper control of flow, friction, &c.; (3) the engines work, as mentioned, upon the gases after their liquefaction (at B), so that all the gas is treated; this feature incidentally avoids the troubles of clogging by frozen impurities and facilitates the purification of the gases. The lowermost of the three engines corresponds to the one Claude engine, but as the initial pressure used is much lower, the temperature range for the engine is also smaller. Since, when expanding a given weight of gas between two definite pressures, the work obtainable (and hence also the number of calories which the expansion will extract from the system) is the greater, the higher its temperature, the uppermost of the three engines will extract most heat and deliver most power to the crankshaft per unit of gas used, and the lowermost engine will extract least heat. Roughly, the Jeffries–Norton arrangement may be likened to a mine which is drained by three pumps installed at different levels, and not, as in Claude, by one pump installed at the bottom of the mine. In the latter case all the water collects in the sump and has to be lifted the full height; in the former case the water collecting near the surface has only to be raised a small height. In these extraction plants the engines have to pump out heat leaking into the system at different levels and temperatures.

Further particulars of these extractions may become available before long and they will be looked forward to with interest. Whether the advantages gained by the addition of the two pumps to the last-mentioned system, remains to be seen. In the actual plants economy will have been a secondary consideration; the experience gained may be all the more instructive.

MERCHANT SHIPBUILDING.

THE returns of merchant vessels under construction, issued this week by Lloyd's Register, show that on March 31 last the number of ships under construction in the yards of the United Kingdom was 657, and the aggregate gross tonnage amounted to 2,254,845. This figure, which is greater than any previously recorded, exceeds that for the previous quarter by about 275,000 tons, and is 375,000 tons more than that for the corresponding quarter of last year. The previous record was reached at the end of the first quarter of 1913, when the merchant ships under construction numbered 563 and the tonnage aggregated 2,063,694 tons. Although the merchant tonnage at present under construction is larger than at any previous time, we still look for a further substantial increase. It must be borne in mind, in this connection, that naval construction is now at a minimum, and also that a number of new yards have been started during the war and others have been considerably extended. The need for ships was never more urgent than at present, and as a large number of men have now been released by the military authorities, there appears to be no adequate reason why the merchant tonnage now under construction should not be greatly exceeded in the near future.

In order accurately to survey the position of the shipbuilding industry it is necessary to consider what is being done abroad. For all other countries of the world (excepting enemy countries for which statistics are not available) the total number of merchant ships under construction at the end of the first quarter of this year amounted to 1,845, aggregating 5,541,421 gross tons. British yards are thus now building only about 29 per cent. of the world's tonnage, whereas for the quarter ended June 30, 1914, the corresponding figure was practically 55 per cent. The difference is actually greater than this, since the figures for 1914 include German and Austrian construction. Of the vessels now under construction abroad no less than 1,155, measuring 4,185,523 gross tons, are building in United States yards; this is an increase of 158 vessels and 539,604 gross tons on the figures for the last quarter of 1918. These data for the United States are extremely interesting, showing, as they do, the remarkable development of the shipbuilding industry in that country as a result of the war. At the end of the second quarter of 1914 the tonnage under construction in the United States was 148,515 (45 vessels), so that the tonnage building at present is more than 28 times as great. On March 31 of this year the British Dominions had 184 vessels under construction, totalling 303,088 gross tons, and Japan comes second on the list of foreign countries with 74 vessels under construction, making an aggregate of 254,835 gross tons. The only other countries with more than 100,000 tons of shipping under construction are Holland with 87 vessels, totalling 182,308 tons, Italy 59 vessels, 135,034 tons; Spain 41 vessels, 122,285 tons; France 33 vessels, 109,795 tons; and Sweden 73 vessels, 100,123 tons.

With regard to the size of the vessels now building in this country the tendency to build a larger number of smaller ships is well brought out by Lloyd's statistics. No vessel now building is over 25,000 gross tons, and only 4 are over 20,000 tons. The vessels of between 10,000 tons and 20,000 tons now on the slips number 18, and between 5,000 tons and 10,000 tons the number building is 236. Of

the latter 150 are between 5,000 tons and 6,000 tons, within which range come most of the general trading ships. In June, 1914, on the other hand, 4 vessels of over 25,000 tons were in hand, and one of these was over 40,000 tons. One came between 20,000 tons and 25,000 tons, and 24 between 10,000 tons and 20,000 tons. Between 5,000 tons and 10,000 tons the vessels then building numbered 103, and of this number only 41 were between 5,000 tons and 6,000 tons.

Of the work now in hand in this country the Clyde accounts for 184 vessels making 754,623 tons in all. Of this number 116 vessels (447,018 tons) are under construction in Glasgow yards, and 68 vessels (307,605 tons) at Greenock. As compared with the previous quarter, Glasgow shows an increase of 38 vessels making 102,568 tons, and Greenock an increase of 17 vessels aggregating 38,875 tons. The respective increases in tonnage are roughly 30 per cent. and 14½ per cent. In Newcastle yards there are now 91 vessels building of an aggregate tonnage of 433,932, as compared with 71 vessels totalling 378,015 tons, at the end of December last. The increase for this district is nearly 15 per cent. Next in order of magnitude comes Belfast and Londonderry, where 46 vessels, with a total tonnage of 317,425 are now in hand—an increase of 7 vessels and 4,650 tons on the figures for the previous quarter. Sunderland now has 59 ships of 259,467 tons in hand, the increase in tonnage being rather less than 8 per cent. on the figure for December, when 54 vessels, totalling 241,175 tons were building in this district. The Middlesbrough district shows an increase for the quarter of 11 vessels, the number now in hand being 42 ships of 148,420 tons in the aggregate. The increase in tonnage in this case, however, is only 1,600. Hartlepool is the only district in which the amount of work in hand has diminished. The number of vessels now building in this district is the same as at the end of December viz., 19, but the tonnage has fallen from 77,200, to 75,600 during the quarter, while at the end of the first quarter of last year the number of vessels building was 22, and the tonnage 96,800. Hull, on the other hand, shows a very considerable increase owing to the fact that a large number of fishing vessels have been put in hand in the district. Hull now has 70 vessels with an aggregate tonnage of 44,825 in hand, as compared with 6 vessels (20,611 tons) building at the end of December. The tonnage has thus more than doubled in this case. The only other districts for which separate figures are available are Liverpool and Barrow. At the former port 20 vessels making 35,585 tons are now under construction, the number having increased by 7 and the tonnage by 1,225 during the quarter. At Barrow the work now in hand consists of 13 vessels with an aggregate tonnage of 31,295, as compared with 4 vessels totalling 25,880 tons at the end of December, and 6 vessels making 13,160 tons at the end of March, 1918. These figures show the gradual change from naval construction to merchant shipbuilding in this district.

In conclusion it may be of interest to note that the 657 ships now building include 49 steel sailing vessels with an aggregate tonnage of 32,396, 39 ferro-concrete barges totalling 27,366 tons, 5 steamers constructed of timber making 1,633 tons, and 1 motor vessel of 200 tons. We may also add that, of the total shipping now under construction in all parts of the world, the tonnage under the survey of Lloyd's Register amounts to 4,597,615, which represents an increase of 150 per cent., in comparison with the figure for June, 1914.

THE EXAMINATION OF MATERIALS BY X-RAYS.

THE general discussion on "The Examination of Materials by X-Rays" by a joint meeting of the Faraday Society and the Röntgen Society, held in the Rooms of the Royal Society last Tuesday, clearly brought out the great possibilities as well as the limitations and difficulties of this promising method of testing materials, which excites far wider interest than might be supposed from the sporadic notes and papers so far published. Great credit is due to Sir Robert Hadfield, Bart., F.R.S., for the initiation of this discussion over which he presided, as President of the Faraday Society, supported by Dr. Batten, the president of the Röntgen Society. The meeting was opened at 5 p.m., resumed after a dinner interval at 8.30, and did not disperse till near 11 o'clock. That is nothing unusual for the Faraday Society. As it was, the remarkably good collection of exhibits by scientists and firms did not receive the attention it deserved, because the instructive character of the discussion kept members within the lecture hall, though several speakers were restricted by official ties. With a very natural pride Sir Robert Hadfield dwelt upon the fact that this was the twentieth general discussion arranged by the Faraday Society, nearly all as successful and crowded as on last Tuesday, when the Society for the first time enjoyed the hospitality of the Royal Society. This is a remarkable record for a comparatively young Society of a little more than three hundred members. As Sir Robert has occupied the chair during the whole war period, he has presided over a good many of these meetings to the success of which, it should be added, he has contributed in manifold ways. Mr. F. S. Spiers, B.Sc., to whose valuable services Sir Robert expressed the Society's indebtedness, has been secretary since the foundation of the Society, the offices of which are at 82, Victoria-street, Westminster.

In his introductory remarks Sir Robert Hadfield said that, when suggesting a general discussion on Radiometallography, he had been quite aware that such an examination for flaws might, if unfairly used, cause manufacturers great trouble and expense, and he had certainly not wished to cast any doubt on the wonderful improvements of the last decades in metallurgical production. His own firm, he might state, had been turning out 8,000 9·2 in. high explosive shells weekly at one time during the war—other firms had done similar big things—and in spite of all the pressure and hurry there had not been a single instance of their products failing through defects; that applied also to some 6,000 guns and tubes for guns, &c. But technologists had to study every new means of ensuring perfect materials. So far X-ray examination seemed limited to thin sections of metal, though some experimenters had dealt, in this country, with specimens of 4 in. and even of 9 in. thickness. Sir Robert had himself submitted to Professor Bragg a large number of purest specimens obtainable in the hope that the X-ray study would clear up the differences in the physical properties of the metals of the iron groups, and the magnetic and other peculiarities of critical points and of allotropic modifications. Those specimens included pure electrolytic iron, various kinds of steel, overheated, cast, &c., several alloys, and manganese metal, cobalt, chromium, tungsten, molybdenum in various conditions. Proceeding to a review of the literature on the subject, which he had conveniently summarised in a bibliography at the end of his paper, Sir Robert drew attention to the X-ray examination of flaky steel by H. S. Rawdon, of Washington—we had a Note on this subject in our issue of last week—to the equipment for X-ray examination which the firm of Henri Pilon had supplied to Messrs. Schneider and other firms; and to two recent German publications on the subject, which Sir Robert had had translated on account of their generally instructive and practical character. Professor Porter subsequently gave an abstract of these papers, copies of which were distributed. Sir Robert Hadfield's own contributions to the researches will presently be mentioned.

In his opening address, Professor W. H. Bragg, C.B.E., F.R.S., of University College, London, stated that it was one of the chief purposes of the conference to display the possibilities of X-ray methods to those who had no occasion to make a study of X-rays themselves. X-rays were of the same nature as light, but of extremely short wave-lengths. Whilst ordinary light gave us information relating to the outward form, the X-rays passed right through a body and revealed its interior condition. For practical purposes X-rays were excited by causing a powerful electric discharge to take place within an exhausted bulb (Coolidge tube), in which the discharge fell on a block of metal, the target or anti-cathode. The actual impact was limited to a small area of the target, the focus; a large amount of the energy unfortunately went into heat, and ingenious devices were adopted to get rid of that heat. The quality of the rays depended upon the target material, tungsten or platinum in the Coolidge tube, but not upon its temperature, and though even rays from tungsten were not quite satisfactory in quality, we had to use such refractory metals which would stand the rise of temperature. For good definition of the radiographs, the focus should be "fine"; but a fine focus would not take much power. The rays emitted from the target in all directions had three main effects; they excited photographic plates and phosphorescent screens, and they ionised gases. The last effect was useful in the laboratory, the second in surgery, but hardly in metallurgy and engineering, and the action on photographic plates would probably be the basis of engineering practice.

The X-rays had the extraordinary property of passing through all substances more or less. The shortest hardest rays, produced by the highest potentials, had the greatest penetrating power, and might alone prove useful in engineering. The transparency of a material to X-rays decreased as the atomic weight increased. Heat had no influence; a red hot casting gave the same radiograph as a cold casting. But owing to that high penetrating power the rays could neither be focussed nor deflected by lenses or prisms. The penetration depended merely on the atomic weight and the thickness of the material. Professor Bragg's exemplified this by a selection of beautiful radiographs. The positive of a watch clearly showed all the parts, wheels, springs, &c.; in a cherry blossom the delicate nerves of the petals were quite distinct; a tadpole which had swallowed a worm looked less dark than the worm which somehow seemed to consist of substances of higher atomic weight; in an electric kettle heater the wire, the porcelain and the star-shaped iron support all cast their shadows. In some photographs of good and faulty castings and welds the tool marks were quite distinct; considering how minute the differences in thickness due to the tool marks were, that fact indicated the truly remarkable sensitiveness of the method.

The explanation of that sensitiveness depended mainly on two considerations. When two X-ray beams of equal initial intensity passed through two slabs of the same material of different thicknesses, the ratio of the transmitted intensities depended only upon the absorption in the extra thickness of the one slab, but not at all upon the absolute thicknesses. If we imagined two beams to strike the photographic plate, the one passing first through steel, the other striking the plate directly, the intensity ratio of the transmitted beams, $T_1 : T_2$ was dependent upon the absorbing power of the steel; if further two equal blocks of some material were interposed in the two beams, both T_1 and T_2 would be reduced, but their ratio would remain the same. Secondly, we had to consider the way in which the photographic image was formed. The blackening of the plate, due to two rays of unequal intensities, increased with the intensity of the rays. The transparency of the plate diminished as the blackening increased, but the ratio of the transparency in two spots, the "contrast" on the plate, was not the ratio of the two ray-intensities. Supposing we had two rays, one twice as intense as the other, and that in the case of the stronger ray, the passage for each period of time reduced the transparency to half its value. In the case of the weaker ray it would always take two periods of time to reduce the transparency to half its value, and when the two transparencies were compared at any time, they would be found not to be always in the ratio 2 : 1. By under-exposure and over-exposure any desired contrast might be obtained, but other circumstances came in, and the plates might become too black; yet by proper manipulation visible contrasts would be secured. Professor Bragg mentioned that Dr. Slade would deal with these points more fully.

Professor Bragg then returned to the question should hard or soft X-rays be used? For penetrating through the material the rays should be hard; but then they penetrated also through the plate, and we had to increase their action on the plate. That action was due to the liberation of electrons which darted to and fro among the surrounding

atoms until their energy was spent. In the emulsion, electrons were set in motion mainly through absorption of X-rays by the silver and bromine, and that action might be reinforced by putting heavy atoms into the emulsion. Some experimenters placed a thin lead sheet on the film, so that the electrons generated in the lead struck back into the photographic plate. The variation in the absorption of rays of different wave-lengths, studied by the Duc de Broglie and others, suggested a further consideration. As wave-length increased the absorption by a given substance also increased; but at a certain value, critical for each substance, the absorption suddenly dropped, to rise again steadily afterwards. There was, therefore, a "step down" in the photograph—it should not be called a band—marking the critical wave-length for silver. A similar "step up," on the side of short wave-length, would be obtained by interposing an absorbing screen, say of antimony or some other metal, in the path of the rays. That "antimony line" was so sharp that it might serve for a new method of spectroscopic examination of the constituents of a material. We might also put some special material in the emulsion and choose X-rays intermediate between the actual value of this material and of the casting under test; but this did not appear practicable. Professor Bragg finally referred to the examination of crystal structures by X-rays, on which he has himself done pioneer work, and which has practical interest to metallurgists. The war, he concluded, had interrupted much X-ray research which might soon be resumed, he hoped.

A paper sent by Mr. E. Schneider, on "The Industrial X-Ray Examination of Metals at the Laboratories of Messrs. Schneider, Le Creusot," was then read in abstract. We reserve publication of this most instructive paper until next week. The radiographs, taken with the apparatus and Coolidge tubes of Messrs. Pilon, exemplified the remarkable influence of aluminium in eliminating blow-holes in fish-plates; the examination of steels containing different percentages of tungsten; and the examination of compound metals. A fault in a cast-steel bracket of a gun carriage was revealed by X-rays and the method changed to avoid repetition of such flaws. The steel specimens so far tested do not exceed 45 mm. in thickness; but that limiting thickness is reduced when the steel contains a constituent of higher atomic weight.

Of the two German papers, already referred to, which Sir Robert Hadfield had had translated and which Professor A. W. Porter, F.R.S., of University College, London, abstracted, the one by Dr. Respondek, of Halensee, near Berlin, outlined "The Principles Governing the Penetration of Metals by X-Rays"; and the other, by F. Janus, of München, and M. Reppchen, of Köln, explained the "Investigation of Metals by means of X-Rays." The latter paper was based upon researches conducted in the laboratories of the firm of Reiniger, Gibbert and Schall, A.G., of Berlin-Erlangen, and was in particular compiled for the technical man unfamiliar with Röntgen-ray bulbs. Perhaps we had better adopt a general tone in our notice, since Professor Bragg had purposely left several points to subsequent speakers.

In the ordinary Röntgen bulb (gas tube) positive ions striking the cathode drive out electrons from the cathode, which, in their turn, hitting the anti-cathode or target, give rise to the emission of X-rays from the target. For the examination of materials we want hard, uniform rays. When we depend upon the ionisation of the gas molecules in the bulb, however, there will be soft as well as hard rays, and the hardness will change during the working. Hence bulbs of the Coolidge type came into use; in these the vacuum is pushed as high as possible. There are hence few gas molecules left that might be ionised, and the stream of electrons required for the causation of the X-rays is obtained by heating to incandescence a Wehnelt cathode or a thin wire of tungsten (the spiral or filament) by a special current; this spiral is surrounded by the cathode proper (the negative pole) of the discharge circuit in the bulb. In the Coolidge tube itself the special heating circuit is a branch of the secondary circuit of the transformer. In the bulb of Professor J. E. Lilienfeld, of Leipzig—which Professor Porter mentioned, was described in 1912, a year before the Coolidge bulb—the cathode is cylindrical and opposite the target as in the Coolidge apparatus; but the filament is of large size; it is not placed within the cylinder, but further away from the target, in a lateral branch of the bulb, and there are three circuits—the heating circuit (potential difference 15 volts, *e.g.*), the ignition circuit (2,000 volts), and the discharge circuit (up to 200,000 volts). The electrons emitted by the hot cathode first travel slowly; entering the cylindrical cathode they are accelerated before they reach the real discharge zone between the cathode and the target. The arrangement is said to suppress soft rays from the outset, and the Lilienfeld bulb differs from the Coolidge bulb as to the peculiar, little noticeable, phosphorescent glow of the glass walls. Lilienfeld has studied these glows, and Janus recommends his bulbs as less likely than others to be pierced when working at high potentials and temperatures. Whether these advantages are real, and whether the Lilienfeld tubes are much used, Professor Porter was unable to say. When gas bulbs become too hard, because the glass walls electrostatically attract the gas (air) molecules and remove them from the bulb, some air is admitted into the bulb from a pocket. This can be done automatically by the aid of a milli-amperemeter acting as a relay. In any case the discharge and hardness are regulated with the aid of an electrometer (called also penetrometer in this connection) and a milliamperemeter.

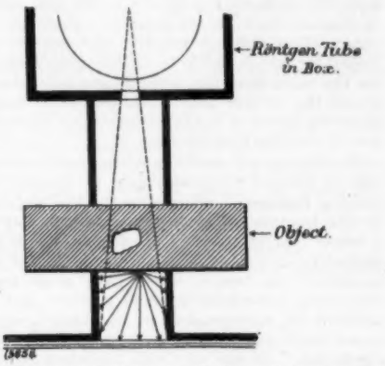
Light radiation passing through a substance will partly be reflected; part is absorbed, part scattered and part transmitted. The absorption of X-rays increases proportionally to the atomic weight in accordance with $J = J_0 e^{-\lambda d}$, where J is the intensity of the absorbed radiation, Jo that of the incident radiation, e is the logarithmic base, λ the coefficient of absorption, and d the thickness of the substance. Instead of λ, μ is sometimes used, being defined by $\mu = \lambda/\rho$, where ρ is the density; the formula is then $J = J_0 e^{-\mu \rho d}$. The absorptions may also be expressed in half-values (similar to the half-life period of radioactive substances), the half value indicating the thickness of the respective material which would stop half the radiation, expressed in centimetres (or fractions of a centimetre) of a foil of aluminium of equal stopping power. The following table summarises the atomic weights A.W., densities ρ, μ/ρ and half values of a few metals for hard rays.

	A-W.	ρ.	μ/ρ	Half-Value.
Aluminium	27·1	2·6	0·07	0·28
Iron	55·8	7·7	7·5	0·012
Silver	107·9	10·5	17·7	0·0037
Platinum ..	195·2	21·5	22	0·0015
Mercury	200·6	14·4	22	0·0022
Gold	207·2	11·4	22	0·0028

In order to secure sharply-defined radiographs the rays falling upon the specimen should be parallel and normal to the plate. As a matter of fact the bundle of rays is conical, and the scattering still more impairs the definition. The scattering takes place in all directions within the specimen and is not confined to the specimen, of course, but the whole air space, and objects in the room help to scatter; rays also fall upon the plate and table by the side of the specimen, and enter the plate from the sides and from below. In order to reduce the scattering the bundle of rays is confined within a tube of lead, and sheets of lead are applied to all the parts of the plate which might be excited by stray radiations. The diagram annexed (from the paper by Janus and Reppchen) illustrates the action in the case of thick specimens. The rays pass through a diaphragm in the bulb casing of lead, down the upper lead tube, through the specimen, down the lower tube and enter the plate, first passing through the intensifying screen which is interposed between the plate and the top of the plate carrier.

The secondary radiation from below is particularly troublesome with thick specimens; if lead sheets, up to 10 mm. thick, cannot conveniently be used, cast lead may be employed, or lead-shot be piled on the parts. For the protection of the operator the bulb is placed within a brick chamber which is fitted with a window of one or several layers of lead glass; switches are mounted on the outside of the wall; further information on these points was given in the paper by Mr. Pichon.

The photographic films must be thick and rich in silver; a slow developer (glycocoll) has to be used, as a rapid developer would fog the surface. The exposure may have to be long, but can much be shortened by the aid of intensifier screens (*e.g.*, of calcium tungstate) which are placed over the plate. The blue light of the tungstate reduces the exposure, to $\frac{1}{8}$ and even much smaller fractions; these screens are delicate, however, and easily stained; they impress the grain of the tungstate crystals on the radiographs and are, according to Janus, apt to impair the definition; the point was not raised during the discussion. With a distance of



about 30 mm. between cathode and target the specimen should be about 40 cm. below the focus of the bulb. In the examination of tubular specimens the films are placed inside the specimen. Blowholes come out much better than cracks; unless parallel to the rays cracks are hardly shown by the X-rays. Faults near the upper surface appear more distinct than faults deeper down. The position of a flaw can be fixed in various ways. A simple method, not always applicable, however, is to take two radiographs on the same plate, shifting the plate laterally for the second exposure. During the exposure the bulb and apparatus must, of course, be kept perfectly steady, a condition not easily realised in works. In ferro-concrete any deformation or rusting of the iron bars can easily be detected. The clean iron gives sharp shadows, the rusty iron thicker, more hazy shadows; Respondek gave a good photograph of a ferro-concrete slab, 20 mm. in thickness, exposed to the rays for five minutes. X-ray testing of the quality of a cement, and the study of the chemical changes going on in cements, have so far failed.

A series of communications on researches carried out by Sir Robert Hadfield, Mr. S. F. Main, B.Sc., and Mr. J. Brooksbank, B.Sc., in the Hadfield Research Laboratory, Sheffield, were then presented. We hope to reproduce some of the photographs next week. The first, on "Testing the Absorption Power of Different Steels under X-Rays," dealt with some of the early experiments. Discs, 1 in. in diameter, $\frac{1}{4}$ in. thick, were placed either on a barium-platinocyanide screen or on a photographic plate. The specimens were a very pure iron (0·03 C, 0·01 Si), density 7·78, forged; a steel with 0·19 C, 0·07 Si and 2.45 Al, density 7·57; and an alloy steel (0·55 C, 2·79 Cr, 20·4 W), density 8·77; the permeability decreased as the density increased, but the differences were not sufficiently marked when the fluorescent screen was used, and the addition of an intensifier proved advisable in the case of the plate. Similar discs, all of the very pure iron, were then prepared, increasing in thickness in steps of $\frac{1}{64}$ in. from $\frac{1}{32}$ in. up to $\frac{1}{4}$ in.; a piece of thin, irregularly-bent iron wire was placed over each disc to help bringing out contrasts; some other steels were tested at the same time. The thicker discs gave darker pictures (all negatives); but a hardened quenched steel disc produced a less dark negative than the annealed specimen. This was contrary to expectation.

The second paper on "X-Ray Examination as Applied to the Metallurgy of Steel," was of a general kind. Steel specimens up to 4 in. in thickness, it was

pointed out, were said to have been successfully examined. To be of actual service the method should allow of examining articles of practical sizes; otherwise the chief advantage of the method, its non-destructive character, would be lost. The examination might be applied to routine examination of castings and forgings in the course of their manufacture, and also to the materials used. Defects such as pipe reproduced themselves under similar conditions of manufacture; but many defects in steel were of a casual nature. Such routine work would much be facilitated if the necessity for photographing could be avoided, and fluorescent screens could be used; for inspection work in particular a simple screen method would be preferable. At present this did not appear to be possible, and the appliances were too costly and delicate. A point to be borne in mind was that the X-ray examination did not magnify the defects to be looked for, which had to be visible to the naked eye. On the other hand the method gave us information about the atomic and crystalline structure, and might be useful in the investigation of allotropy as also in metallurgical analysis.

The third paper, on "The Radiographic Examination of Carbon Electrodes used in Electric Steel-making Furnaces," referred to the troubles caused by the fracture of the electrodes, which may spoil a whole cast of steel. The carbons, up to 20 in. diameter, are made of amorphous carbon or of graphite; the former, which gave most trouble, were more heterogeneous than graphite and more suitable for radiography, it was stated, and the paper dealt particularly with amorphous carbon electrodes. In the electrode manufacture, retort carbon, anthracite or petroleum coke or mixtures of them are crushed and mixed with pitch and tar to be moulded under pressure, in cylinders or by extrusion, and then baked. The paper contains particulars as to diameter, ash contents (generally about 4 per cent., 15·8 per cent. in one case), actual and apparent gravity (ranging from 1·8 to 2.2 and 1·47 to 1·65), and porosity (3·5 per cent. to 33·8 per cent., the carbon mentioned rich in ashes having a porosity of 11 per cent.), of eight samples from different firms. Sections, 1 in. in thickness, were examined by Messrs. H. W. Cox and Co., with a Coolidge tube, 6-in. spark gap, 20 in. distance anode to plate, 2 milliamperes and exposures of 1 minute, which might have been reduced. Positives were afterwards prepared from the negatives in the Hecla Works of Messrs. Hadfield, and these positives are much clearer, it was stated, than the negatives reproduced in the paper. In one set of experiments small boxes of the materials used, retort carbon, pitch, and anthracite were radiographed together with the respective electrodes; those pictures afforded little further information, probably because the baking altered the raw materials too much. The information gained as to the structure was considered valuable, though the interpretation of the radiographs did not appear to be easy. A coarse structure was not found detrimental to good behaviour, i.e., freedom from fracture; the specimen richest in ashes [a point to which attention is not drawn in the paper, we should say] proved the best electrode; it was of a very coarse structure, but the worst electrode was also very coarse, and the electrode of finest grain proved only of average quality. A systematic investigation, the authors stated, of electrodes of various compositions, baked at different temperatures, &c., appeared desirable and might explain the appearance in the radiographs of some very dark grains, possibly grains in the process of assimilation. Some graphite electrodes gave radiographs devoid of any structure; in one of them a crack was shown.

The fourth paper from the Hadfield Research Laboratory was on "A Method of Testing an X-ray Tube for Definition." We shall later notice this paper together with others of a similar nature.

In a short note on "The Detection of Hair Cracks in Steel by X-rays," Lieutenant-Colonel C. F. Jenkin stated that he had been persuaded to try whether it would be possible to detect hair cracks which had given considerable trouble in the crank-shafts of aero engines, though there seemed to be little likelihood of success. The samples had been examined by the experts who were pushing the process. The samples were cut from crank-shafts with large and relatively obvious flaws; but no trace of defects was shown by the X-rays. One sample, about 2 cm. thick, was cracked right through the thickness for a length of 6 cm.; but the radiograph gave no indication of the crack. If such large flaws were undetectable by the X-rays, the method was obviously useless for finding hair cracks, Colonel Jenkin remarked, adding that he did not follow Professor Bragg's arguments concerning the explanation of the detection of minute differences in the sheet thickness by means of the rays.

(To be continued.)

GRINDING COKE SAMPLES FOR ANALYSIS.—In *The Gas World* of February 1 last, Mr. J. Hughes discussed a case of contested analysis concerning the delivery of a coke which different analysts reported to contain from 1 per cent. to 5·6 per cent. of ashes. Mr. Hughes suggested that, when the coke is ground with the aid of an iron pestle and mortar, it would become contaminated with iron, whereas the coke, crushed to small fragments while confined in a strong linen bag and then ground in an agate mortar, would not be contaminated. Treating samples of the same coke by the two methods he found 4 per cent. and 1 per cent. of ashes respectively. In the former case iron could be picked out of the coke by a magnet. Following the problem up, Mr. A. E. Findley, of the University of Sheffield (Journal Society of Chemical Industry, April 15, 1919) observed that all coke samples ground in an iron mill were magnetic. From one sample with 35·4 per cent. of ash, 12 per cent. could be separated with a magnet, and they yielded 67 per cent. of ash, whilst the other part yielded 27 per cent.; the coke itself was probably magnetic owing to the reduction of pyrites during coking. A clean coal with 1·55 per cent. of ash was coked in a platinum crucible and then ground up partly in agate, partly in iron; the ashes found were 1·7 per cent. and 1·9 per cent. respectively. This coke was soft. But in various other samples of hard coke grinding in agate or in iron hardly affected the ash percentage either. In a Durham coal, grinding in iron raised the ash percentage from 7 to 8·4, and grinding in hardware from 7 to 8·5; in the former case the ash increase was due to iron oxide of which 3 per cent. (instead of 1·9 per cent. in the agate-ground coke) were found, in the second case other impurities were taken up from the hardware. Mr. Findley therefore concludes that the abrasion leading to an increase in ash takes place chiefly during the reduction of the pieces of coke to coarse powder, and that the subsequent grinding, whether effected in an iron mortar or in an agate mortar, has little or no influence. The disintegration in linen bags might itself cause contamination, but scarcely of any importance.

AUTOMATIC ESTIMATION OF SMALL AMOUNTS OF OXYGEN AND COMBUSTIBLE GASES.—In the course of their investigation of the synthetic ammonia process, conducted at the Munitions Inventions Department, Dr. H. C. Greenwood and Mr. A. T. S. Zealley devised an automatic apparatus which indicates the amount of oxygen present in the nitrogen and hydrogen, and also gives a warning when the percentage of oxygen—which would interfere with the catalysis and might cause explosions—exceeds a certain value. The principle of the apparatus is that, when a known volume of the gases is left in contact with a hot platinum wire (electrically heated), the oxygen will burn an equivalent amount of hydrogen, and the gas volume will hence be diminished; from the contraction the percentage of oxygen can be estimated, and the rise of the mercury in the respective glass tubes can be made to close the circuit of an alarm bell. On the other hand, the presence of small quantities of hydrogen or other combustible gases in air can likewise be detected in this way, and the amount of methane in mine may be estimated by the same method. The apparatus, described in the Journal of the Society of Chemical Industry of April 15, 1919, consists of a system of glass tubes, partly filled with mercury and water, working on the siphon principle. The first operation makes the mercury rise, to open and then to close the gas burette which thus becomes filled with the gas mixture to be tested; the electric current is, at the end of this first phase, automatically switched in, and the thin platinum wire in the burette is rendered red hot; white heat, it has been ascertained, is not needed for the combustion. The second operation cuts off the electric current; the third allows the mercury to sink to its original low level. The burette is then cooled by the water flowing through its jacket, and the burette is several times flushed with fresh gas mixture and kept refilled for a new analysis. For a burette of 50 cub. cm. capacity the rate of gas flow through the apparatus need not exceed 1 cub. ft. per hour. It will be noticed that absorbent liquids or solids are not used. The apparatus, which fits into a small glass-fronted case, has given very little trouble in continued practical operation. As described the apparatus—not novel, of course, in principle, but novel in its automatic operation and compactness—would be very convenient for automatic testing in cases where only one combustible gas is to be reckoned with. The apparatus is valuable in particular also because it furnishes a continuous automatic control of the purity of the gases used in continuous processes. A test takes a few minutes, and 0·1 per cent. of oxygen can be detected.

NATIONALISATION OF COAL MINES.

TO THE EDITOR OF ENGINEERING.

SIR,—Sir Leo Chiozza Money is reported to have informed a witness that the Australian State Railways were making a profit on low rates of freight and passenger fares; the impression intended to be conveyed being that these have been reduced under State management. It is of great importance that assertions such as this should be verified, and supported, by proof of their accuracy, for they are generally accepted in good faith as facts by the majority of the people.

I am in the belief, derived from articles in your journal on the Australian State Railways, that when they were private companies they were paying a dividend on lower rates than are now charged by the State. This was confirmed by two Australian State Railway servants, whose acquaintance I made during the war. Both are employed on the Western Australian State Railway; one is a Scotchman and the other an Australian. Both informed me that under State management freights and fares had been raised before the war, to pay the increased staff and the higher wages they were getting. They said that State railways were a fine thing for railway servants and politicians, for each backed the other up in making fresh demands, but were a bad thing for the country and the mass of the people.

Yours faithfully,

Carnoustie, April 28, 1919. PETER SWAN.

THE COST OF THE MINISTRY OF LABOUR.

TO THE EDITOR OF ENGINEERING.

SIR,—According to the last issued statement of accounts, that for the year ending March 31, 1918, the Ministry of Labour cost the country the sum of 1,859,815*l.*, which is detailed as follows:—

	£
Buildings, maintenance, furniture, &c.	146,063
Surveys	1
Rates	18,131
Cost of audit	3,267
Printing and stationery	69,680
Superannuation	2,710
Postage, telegraphs and telephones (excluding war expenditure)	83,647
Miscellaneous	50
Expenditure (gross) shown in appropriation account	2,065,901
Total	2,389,450
Deduct realised appropriations in aid and other receipts	529,635
	1,859,815

The appropriation account is given as under:—

	£
Ministry of Labour, salaries, wages and allowances	13,276
Travelling expenses	600
Incidental expenses	296
Law charges	1,590
Employment Department.	
Salaries, wages and allowances	829,364
Umpire and Courts of Referees	4,813
Travelling expenses	36,216
Incidental expenses	8,304
Advances to workpeople	86,141
Cost of stamps (manufacture and paper)	1,488
Contribution to Unemployment Fund	1,007,541
Repayments to associations	18,270
Women's Army Auxiliary Corps, expenses of recruiting	11,742
Losses	36
Compensation	7
Industrial Commissioners' Department.	
Salaries, wages and allowances	10,944
Travelling expenses	826
Incidental expenses	99
Fees and travelling expenses under the Conciliation Act, 1896	20,166
Trade Boards.	
Salaries, wages and allowances	8,058
Travelling and incidental expenses	6,114
Total, with odd shillings and pence,	2,065,901

The 529,635*l.* mentioned above as appropriations in aid and other receipts is explained in the following manner:—

	£
Received from the Unemployment Fund in respect of salaries, remuneration and expenses	444,783
Repayment of sums advanced to workmen	68,506
Miscellaneous receipts, including sums for services rendered for charges for the issue of new employment books, law costs recovered and other receipts	16,345
Total, with odd shillings and pence,	529,635

Now the question which we as business men and taxpayers have to ask ourselves is whether we are getting value for this great sum of money? Are we acting wisely or unwisely in allowing our paid servants in high

places to spend so much money on this account? Is the total cost capable of reduction without any sacrifice of value to the community? It must be remembered that these Government accounts are not subjected to any outside audit. This account is signed by the accounting officer and certified as correct by the Comptroller and Auditor-General. In other words, by employees of the same firm, and it does not come under the scrutiny of any commercial auditor representing the taxpayers who have to shoulder this great burden.

Where is it going to end? How much higher are the costs of these Government Departments likely to be? Parliament has long since ceased to exercise any effective control over expenditure, and the task is far too great for it to accomplish if it is to give due consideration to the large matters of home, colonial and foreign policy by which it is confronted. What is the remedy for this state of affairs? Are we to become the slaves of our own paid servants and pay calmly whatever demands they choose to make? Is the nation willing to support this great horde of officials who are now eating its very life. The remedy lies with the organised traders and business men of the country who must demand an independent investigation into the expenditure and methods of book-keeping of all Government offices. If once our Chambers of Commerce and trade societies take up this question and criticise Government expenditure there will soon be a heavy reduction of taxation and a consequent easing of the industrial situation for the nation.

Yours truly,
RICHARD HIGGS.

Shepherdswell, Dover.

"COAL SAVING AND SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

TO THE EDITOR OF ENGINEERING.

SIR,—I think it must be admitted that Mr. Dunlop's recent letters have provided much food for thought amongst those interested in the operation of boiler plant. At first sight some of the statements have certainly appeared rather peculiar, but when the subject is approached with an open mind, and the facts thoroughly studied, one cannot help thinking that Mr. Dunlop has given very many years' consideration to the matter, and has arrived at some very important conclusions.

Destructive criticism from anonymous correspondents is of no value, and to suggest, as "R" does, that Mr. Dunlop is unaware of the usual grate area in a Lancashire boiler is obviously rubbish.

One point I should like to raise is that it would have put the matter on a far better basis if actual comparative test results on ordinary boiler plant had been quoted. Reference was certainly made to some tests on a special boiler fired with peat, but I have no doubt that Mr. Dunlop could offer us some more useful information in this line.

I consider it would be of very great help to young engineers, not to speak of some of the older members of the profession, if Mr. Dunlop would write a series of articles giving his theories in full, with whatever practical results he has to back them up. Advanced theories such as these are apt to become somewhat disjointed when put forward in correspondence.

There is just one more point on which further information would be of value. It is stated that—

$$\text{Efficiency at increased rate} = \frac{\text{Efficiency at given rate}}{\sqrt[3]{\text{Ratio of increase in rate of firing}}}.$$

Taking one of the examples given. Efficiency is 80 per cent. at 30·3 lb. per square foot grate per hour. What would the efficiency be at 20 lb.? How is the law applied when a decrease is to be considered?

I am, yours faithfully,
Belfast, April 29, 1919. GEORGE H. GILL.

TO THE EDITOR OF ENGINEERING.

SIR,—The only error I am conscious of making in my letter published in your issue of 21st ult., is an error your correspondent "R," in his letter published on page 548 of your issue of April 25, has entirely overlooked. I used the cube root instead of the square root when calculating the decrease of efficiency under forced draught. In all probability the young engineers your correspondent fears may be misled have already made the correction for themselves. In fact, my letter was written in the hope that some of the young engineers would contribute to your pages the modern method of calculating boiler proportions and performances. Old engineers like your correspondent and myself do not really know everything about steam boilers, and for my own part, I am at all times ready to acknowledge errors. When, however, I am told that my letter contains several errors, that one quantity is not rational, and several other quantities are not relevant, I naturally expect to find such assertions accompanied by an exposure of the enormity of my mis-statements and misrepresentations. Your correspondent's letter contains nothing of that nature, and consequently the extent to which I have misled young engineers is an unknown quantity. It may be some measure of compensation if I state the only ways I know of saving coal in steam boilers:—

First. By using the amount of air that will ensure the highest efficiency of combustion of the coal used. In my previous letters I have given the formula by which that amount of air can be calculated for any class of fuel.

Second. By using the smallest size of grate that will enable the desired output to be attained. It will be recognised that the smaller the grate the smaller the quantity of coal it will be possible to waste.

Third. By using a boiler that will give the desired output at a low rate of evaporation per square foot of heating surface. I have given the relation of quantities by which this rate can be calculated. It will be recognised that resistance to transmission of heat through the plates will be less at low than at high rates of evaporation, and consequently less coal will be wasted in overcoming resistance.

All other ways of saving coal that I know of are separate or distinct from the boiler. Economisers, of course, can be treated as part of the boilers they operate in connection with.

It is possible I may be wrong in thinking the only way to save coal is to prevent waste, but such observations as I have been able to make on the operation of steam boilers give me confidence in that belief.

Yours truly,
JAMES DUNLOP.

190, Bellfield-street, Dennistoun, Glasgow,
April 26, 1919.

SLIDING FRICTION IN BALL BEARINGS.

TO THE EDITOR OF ENGINEERING.

SIR,—After having read the remarks made by Mr. W. E. Baker, in his letter published on page 373 of your issue of March 21 last, and directed against my calculation of the sliding friction in ball bearings, I find it necessary to give you some particulars, which will help to make clear the accordance of the calculations with practice.

The object of my calculations was to confirm theoretically what has been observed in practice, i.e., that a spherical ball bearing has a considerably smaller coefficient of friction than the grooved bearings. The friction in a ball bearing consists of a combined rolling and sliding friction. The rolling friction as such is probably the same for both types of bearings, while a considerable difference is to be found in the sliding friction.

The total friction can easily be measured. I can also give you a great many results of friction measures, which are to be found in the following table:—

Revs. per Min.	Load, Kg.	Spherical Bearing.	Grooved Bearings.			
300	475	0·00079	0·00091	0·00093	0·00127	0·00121
300	870	0·00075	0·00096	0·00095	0·00130	0·00103
300	1,260	0·00082	0·00111	0·00108	0·00154	0·00096
800	475	0·00095	0·00105	0·00109	0·00143	0·00182
800	870	0·00087	0·00100	0·00111	0·00129	0·00130
800	1,260	0·00085	0·00115	0·00108	0·00165	0·00117
1,250	475	0·00115	0·00136	0·00128	0·00172	0·00201
1,250	870	0·00098	0·00114	0·00111	0·00157	0·00151
1,250	1,260	0·00096	0·00126	0·00110	0·00150	0·00130
1,750	475	0·00143	0·00151	0·00155	0·00192	0·00212
1,750	870	0·00112	0·00122	0·00121	0·00168	0·00156
1,750	1,260	0·00104	0·00131	0·00122	0·00169	0·00133
2,250	475	0·00181	0·00200	0·00206	0·00232	0·00220
2,250	870	0·00125	0·00138	0·00146	0·00190	0·00149
2,250	1,260	0·00110	0·00133	0·00139	0·00177	0·00124
Mean	..	..	0·00106	0·00125	0·00124	0·00163	0·00150

These measures are taken on bearings of different manufactures with the bore 45 mm., outside diameter 100 mm. and width 25 mm. Each coefficient of friction given in the table is the mean value for four bearings. It is found that the grooved bearings have on an average 33 per cent. greater total friction than the spherical bearings. This is, therefore, the fact that was to be explained by my calculations, and I venture to say that I have succeeded in my endeavours. Out of my results Mr. Baker tries to calculate the effective coefficient of friction, but in doing so, he does not observe that I have only given the loss of energy through sliding at the heaviest loaded ball. But it is clear that to this ought to be added the losses at the other balls and finally the pure rolling loss for all the balls. It is therefore quite natural that the result obtained by him, will be too low.

In my article I have calculated the spinning in a spherical bearing and found that this is of very little importance, and that it can be left out of question in connection with the other sliding. The sliding caused by the spinning represents only a small percentage of the total friction.

I have personally a sufficiently long practical experience of ball bearings to be able to affirm that this calculation very well corresponds to reality.

A ball bearing is well constructed, if the friction in it is small and its carrying capacity is great. It might be very well known that the carrying capacity of the spherical bearings in regard to principally radial loads, for which the bearings are intended, is at least just as great as that of grooved bearings, as the spherical bearings for more than ten years have been extensively used in all countries. But there is besides this something, which has never been observed to the same extent, and that is the low friction, with which I have therefore been induced to deal more minutely.

Yours faithfully,
Göteborg, April 4, 1919. ARVID PALMGREN.

DRAUGHTSMEN.

TO THE EDITOR OF ENGINEERING.

SIR,—May I ask the indulgence of your columns to appeal to the engineering and shipbuilding draughtsmen of the country seriously to consider the "advanced labour policy ideas" at present being pushed forward by the leaders of the Association of Engineering and Shipbuilding Draughtsmen. I understand that the association is now affiliated to the Parliamentary Committee of the Trades Union Congress, and, further, that there is a strong effort being made to affiliate with the official Labour Party with a view to political action.

I am, of course, aware that this latter proposal is opposed by some of the best intellect among the leading lights of the association, but I fear that the "advanced party" will prove too strong for the more careful and steady-thinking leaders, and before the members of the association in general realise the position, the association will be committed to a policy that will not be acceptable to its older and more worldly experienced members, who, perhaps, in point of actual numbers, are in the minority.

I believe the original propaganda of the association definitely stated that it was to be run on such lines as would not interfere with the political ideas of its members, but I venture to say that such a policy as affiliation to the Parliamentary Committee of the Trades Union Congress, and such-like political or semi-political affiliations are *not* in accordance with the policy that was held up to catch members some two or three years ago.

I know that I shall be told that it is up to the members to throw out these ideas if they do not approve of them, but, alas, the vast majority of members *do not* attend the branch meetings, and consequently do not realise until *too late* that they are committed to a policy that is probably entirely antagonistic to their views and wishes.

I would, therefore, strongly urge all members who are not of the so-called "advanced party" to attend the branch meetings and give voice to their opinions, and show by their votes that they are not going to be led by a small coterie of aspirants to political fame.

Further, I would, with all due deference, warn these "advanced leaders" that they are hastening the day that will cause a split in the ranks of the association, when the senior draughtsmen will cut themselves adrift from their parent body and probably join with a "society" whose ideas are not quite so far "advanced" as those being hurried forward by the present executive of the Association of Engineering and Shipbuilding Draughtsmen.

Yours faithfully,
"O. L. D."

April 24, 1919.

LARGE AUTOMATIC STOKERS.—The Charing Cross, West End and City Electric Supply Company, Limited, have placed a repeat order for four more 12-retort Erith-Riley stokers, each being applied to a water-tube boiler with 10,850 sq. ft. heating surface. The existing Erith-Riley stokers were described and illustrated in ENGINEERING of February 28 last. Each 12-retort stoker is applied to an archless furnace, 21 ft. wide, and has a normal capacity of 3 tons of coal hourly, continuously discharging the incombustible ash.

FRENCH WATER POWER INSTALLATIONS.—Our French contemporary, *Revue Générale de l'Electricité*, has issued, at the price of 12 francs, a guide book entitled "Annuaire de la Houille Blanche Française," by Mr. Auguste Pawlowski, giving interesting information on all the French companies' stations driven by water power, and either distribute electric current for both light and power, or utilise the current they generate by water power in their own works for various industrial purposes. The information given comprises a brief history of the undertakings, the indication of the capital, the nature of the installation, balance-sheet, board of directors, &c. Special chapters deal with the French legislation on water power utilisation, with the extent to which water power was taken advantage of during the war, and with cognate subjects.

H.M.S. "CRETEHAWSER."—H.M.S. Cretehawser, a single-screw tug of reinforced concrete, built by the Wear Concrete Building Company, Limited, at Southwick-on-Wear, has just successfully completed her official trials at sea off the mouth of the River Tees. The triple expansion engines and boilers built by the Central Marine Engine Works of West Hartlepool, worked throughout the trials without the slightest hitch. The trial was of 4 hours' duration, and included four full-speed double runs over a measured course, resulting in a mean speed of close upon 10¼ knots. Steering and anchor trials were also carried out most successfully, and the ship gave every promise of being an excellent sea boat and a powerful ocean-going tug. The Cretehawser is 125 ft. long and 27½ ft. broad, and is the first reinforced concrete tug to be built in this country.

ELECTRICAL TRADES DIRECTORY AND HANDBOOK.—We have just received from Messrs. Benn Brothers, Limited, of 8, Bouverie-street, London, E.C. 4, a copy of *The Electrician* "Directory and Handbook of the Electrical Engineering and Allied Trades for 1919"—the thirty-seventh year of issue. In spite of the difficulties the publishers must have experienced, on account of the war, in collecting data, the contents of the current volume appear to be in every way equal to those of earlier editions. About a third of the volume is taken up by the handbook section, in which are to be found technical notes and data, financial and commercial notes, information on cable and wireless telegraphy, lists of technical societies and educational institutions, and a valuable digest of the law relating to electric light, power and traction. This is followed by lists of British firms in the electrical and allied trades classified alphabetically and according to their productions. Similar lists are also given for colonial and foreign firms, and reference to each section is facilitated by thumb-holes cut in the edges of the pages. The volume contains over 1,300 pages, strongly bound in blue cloth covers, and its price is 15*s.* net.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 16th ult., at the Society's Rooms, 70, Victoria-street, Westminster, Mr. F. J. W. Whipple, M.A., vice-president, in the chair.

Mr. Alfred A. Barnes, F.R.Met.Soc., M.Inst.C.E., read a paper entitled "*Rainfall in England: The True Long Average as Deduced from Symmetry.*" It has been usual to assume that the average annual rainfall during any period of thirty-five years can be adopted for obtaining the "long-average" at any rain gauge, but the author considers that the fluctuations which occur between such averages for various thirty-five-year periods tend to show that the basis is somewhat uncertain. By an exhaustive analysis of the annual readings at 38 rain gauges in England during the sixty-two years 1856–1917, the author proves that variations of as much as 5 per cent. on each side of the mean are quite possible when dealing with successive thirty-five-year periods. From these same records it is then shown that far greater consistency in the value of the average can be obtained by taking periods symmetrical about the end of the year 1886. Both by means of tables and diagrams the author shows that that date is a very critical one in regard to rainfall in England, and that as a rule the years before that date were relatively far wetter than years subsequent to it. Hence the balancing of the earlier wet years by the later dry years establishes the principle of symmetry about that date, and it is shown that by this method the maximum departure from normal which results from taking each of the 15 long periods symmetrical to the end of the year 1886 does not exceed 1 per cent. in the case of any of the 38 gauges which were examined.

Mr. C. E. P. Brooks, M.Sc., F.R.Met.Soc., also read a paper entitled "*The Secular Variation of Rainfall.*" In order to obtain a measure of the secular variation of rainfall during the past thirty to fifty years, correlation coefficients were worked out between the annual rainfall at each station and "time," the measure of the latter being the number of years before or after the middle year of the series. This was done for 162 stations distributed over the globe, and the results were charted on a map. This map shows that the greater part of the world is divided among a few definite regions of wide extent, in each of which the rainfall has been either increasing or decreasing. The most important area of increasing rainfall is temperate Eurasia (except the western seaboard); other areas are south-east South America and the south of Australia. Areas of decrease are the tropical regions as a whole, South Africa and the West Coast of Europe. It is noted that the number of sunspots and also of solar protuberances during the period in question have been decreasing. For a few stations records of longer period are dealt with, giving indications that the results obtained are due to a periodicity of upwards of fifty years.

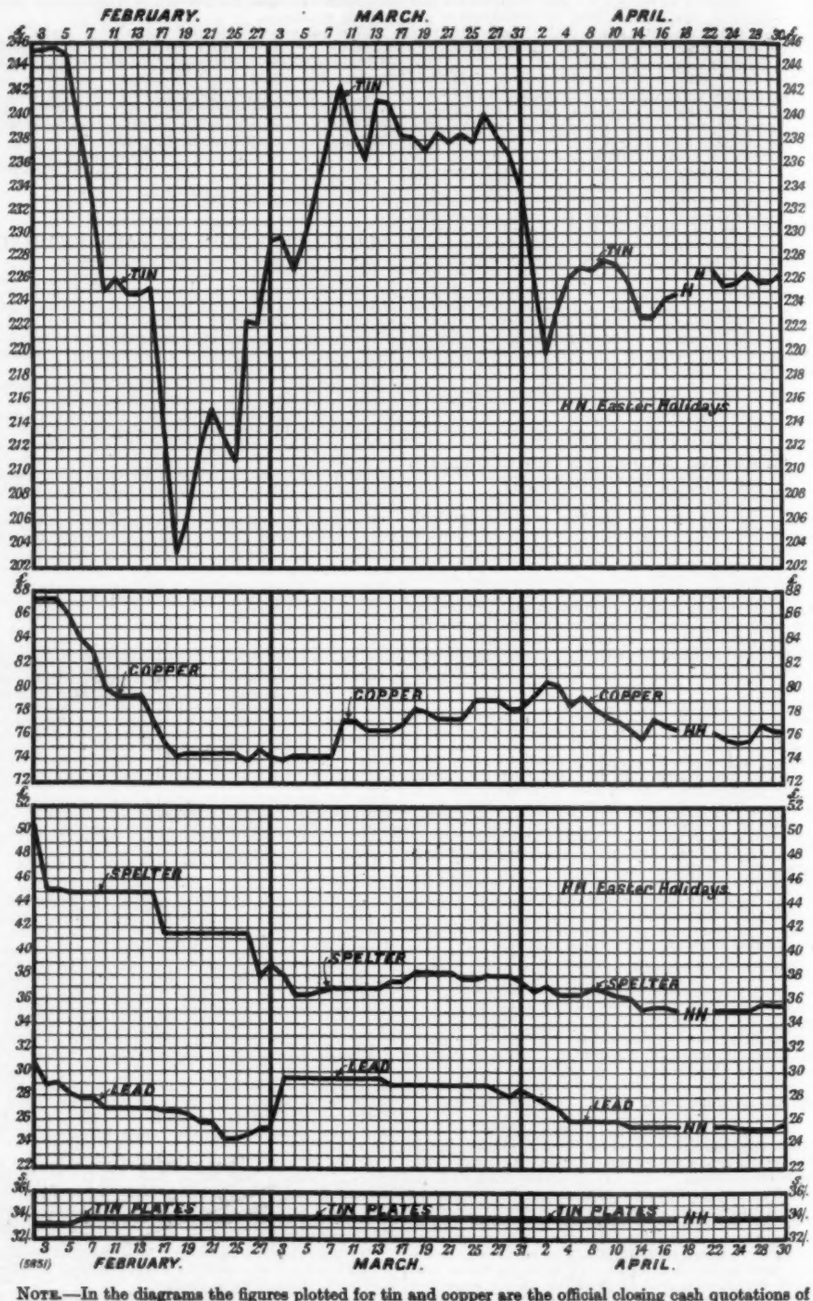
REINFORCED CONCRETE DESIGN.—A short course on Reinforced Concrete Design will be held at University College, London, during the summer term. It will consist of about 20 lectures, and may be extended to include Drawing Exercises. Further particulars, including a syllabus of the lectures, may be obtained from the Secretary, University College, London (Gower-street, W.C. 1).

THE INSTITUTION OF ELECTRICAL ENGINEERS: INFORMAL MEETINGS.—The next informal meeting will, by kind permission, be held in the rooms of the Chartered Institute of Patent Agents, Staple Inn Buildings (South Block), close to No. 335, High Holborn, W.C., on Monday, May 12, 1919, at 7.30-p.m., when Mr. W. E. Bradshaw will open a discussion on "Regulations Issued by Electricity Supply Undertakings."

THE LATE MR. J. SCHMID-SULZER.—Mr. Jacob Schmid-Sulzer, who died suddenly a few weeks ago, in his seventy-eighth year, was for nearly thirty years chief engineer of the turbine department of Messrs. J. J. Rieter and Co., of Töss, near Winterthur, Switzerland, and as such prominently connected with many well-known hydraulic installations. Born at Schopfheim in 1841, he went to the Technical High School at Karlsruhe after practical training in a workshop and a foundry, but had temporarily to abandon his college studies owing to severe illness. Having then spent two years in drawing offices, he worked under Mr. Girard, in Paris, and resumed his studies there, at the Institut Polytechnique. After holding several appointments, one of them being that of manager of some cellulose works near Strassburg, which were destroyed by fire, he accepted the post of turbine engineer to Messrs. Rieter, in 1878. Girard turbines were then in general favour. The turbines which he built in his early practice for the Acquedotto de Ferrari-Galliera, for the Società degli Alti Forni and Fonderie in Terni (52 turbines), the Société Electro-chimique in Vallorbe, and other plants, were all of the Girard type, but the adoption of high falls, of 180 m. in 1880, and even of 550 m. in 1886, was his own risk. Later when the development of electricity works put new problems to the hydraulic engineer, Schmid perfected the Jonval turbine; such turbines were installed in the works of the Aar- and Emmen Canal, in the electricity works of the town of Aarau, at Bellegarde (3,800 h.p.), in Wynau (seven turbines aggregating 4,000 h.p.), and in the extension of the Sarpfos plant in Norway (eight turbines totalling 7,000 h.p.). Schmid—the additional name, Sulzer, is that of his wife, according to Swiss custom—retired in 1905, but remained active and equally popular in industrial and social work. Several of the installations we mentioned have been described in our columns.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7, 1916, the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig-iron was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. (For official regulations see page 45, vol. cii.) A new series of prices for iron and steel has been issued, and appeared on page 646 of our issue of December 6, and on page 23 of our issue of January 3. The Minister of Munitions has also issued certain regulations controlling the prices and dealings in non-ferrous metals; these restrictions were removed on December 17.

PERSONAL.—Mr. W. J. John, D.I.C., A.M.I.E.E., has been appointed lecturer in electrical engineering at East London College (University of London). Mr. John was trained at the City and Guilds (Engineering) College, South Kensington, and has since been for 2½ years assistant designer to Messrs. J. H. Holmes and Co., Newcastle-on-Tyne, and afterwards as wireless engineer in the service of the British Admiralty. Latterly he has been experimental and research engineer with Messrs. Allen, West and Co., Limited, Brighton.—Mr. G. V. Twiss, M.I.E.E., who has for the past ten years been technical adviser to Messrs. Bullers, Limited, has now founded a new company—Twiss Engineering and Electric Transmission, Limited—whose head offices are at 62-63, Queen-street, London, E.C.4, and who have affiliated works at Mildmay Park, N.

PRE-WAR WARSHIP DESIGN.

*Ships of the British Navy on August 4, 1914, and Some Matters of Interest in Connection with Their Production.**

By Sir PHILIP WATTS, K.C.B., F.R.S., LL.D., D.Sc., Hon. Vice-President.

Now that the war is presumably over and the world's affairs have reached a stage which could not have been reached but for the British Navy, it is desirable that we should have on record in our Transactions a statement of the constituent elements of that Navy as they existed in commission and in course of preparation at the outbreak of war in 1914 and of those of the other navies concerned.

I became Director of Naval Construction in 1902, and held the post for ten and a half years till August, 1912. I continued an Advisor to the Board after that date until and after the declaration of war with Germany. It has been pointed out to me by members of our council that I should prepare this paper, and at the suggestion of Admiral Sir Henry Jackson I applied to the Admiralty and obtained permission to put forward the particulars which accompany these remarks. Ever since this Institution was founded in 1860 it has discussed matters having to do with the *materiel* of the Navy. Questions have on various occasions been referred to it informally by the Board of Admiralty, and its discussions have had weight with the Board arriving at decisions.

"All the ships which formed our Navy at the outbreak of war were, I think, designed and built by present and past members of our Institution. Our members, both past and present, though they may not have been personally engaged in the designing or building of our fleets, have nevertheless done much to bring those fleets into being. Their papers and discussions before the Institution and, in some cases, their Parliamentary and other action, have been of great service. A large number of eminent naval officers have contributed to the same great object; in some cases they have contributed the facts and have adopted the results arrived at after discussion. I submit that collectively, the Empire, and indeed the world generally, owes much to our Institution for its services in connection with the production of the vessels which have played so important a part in securing the world's freedom.

It is not necessary to enumerate at length the names of those I have referred to, whether of naval architects, marine engineers, or naval officers. To make a selection would be invidious, yet I feel I may mention in this connection the name of the late Earl Brassey, who, though neither a naval architect nor a naval officer, was one of our original members, and served us well from our inauguration to the time of his death. No one had the interest of British shipping, either war or mercantile, more at heart than he had, or worked harder to secure its well-being and efficiency. His name is ever present with us in connection with this paper because of the lists of warships, and the complete information as to the navies of this and other countries which have appeared in "Brassey's Annual" for many years down to the present date. May I also mention Lord Fisher, the naval officer who for forty years has had much to do with matters connected with the design and construction of our warships, who certainly had more to do than any other man with fixing the broad features of the ships of the British Navy as they stood prepared to meet the Germans in August, 1914, and to whom the efficiency of the *materiel* of the fleet must mainly be attributed.

The present paper is necessarily largely statistical. It must also be considered in connection with, and as a supplement to, my paper to our Institution in 1911, entitled "Warship Building, 1860–1910." That paper dealt at considerable length with the warships of all the principal maritime countries during the period 1860–1910. The present paper deals mainly with the British warships in commission, building and completing in August, 1914, and the circumstances somewhat prior thereto. Some account has also been given of the fleets of our Allies and of our enemies, but such accounts can obviously not be complete, much less exhaustive. The larger auxiliaries of the War Fleet, such as floating docks, coaling vessels, &c., important as they are, are not referred to in any detail in this paper.

One feature emerges quite clearly from the tabular matter attached hereto, and that is the great homogeneity of the several fleets at the outbreak of war.† In the 'seventies and 'eighties of the last century the designs of warships were in such a state of flux that it would then have been impossible that fleets of several units should be found to possess even approximately the same features of speed, armour protection, gun and torpedo armament, radius of action, &c. In August, 1914, the case was entirely different. The story of how this change came about has been told by many writers elsewhere, and I do not propose to enlarge upon it now. I will only make such reference to it as shall lead up to the consideration of our war vessels in commission, building and completing in August, 1914.

During the early stages of the construction of our armoured battleships, guns rapidly increased in power, armour increased in thickness, and the disposition of the guns was constantly being varied with the object of securing powerful bow and stern fire, and commanding as much as possible an all-round fire. Speeds, however, for many years were kept at about 14 knots.

At an early stage Captain Cowper Coles strongly advocated the mounting of guns in revolving turrets well protected by armour, and the Royal Sovereign, a wood line-of-battleship, was converted to this system. She can hardly be described as a successful sea-going ship, and did very little sea service. She, however, drew prominent attention to the advantages of the turret system of mounting, and the Admiralty, with Sir Edward Reed as Chief Naval Constructor, built the Monarch at Chatham, completing her in 1869. She had a large sail spread and was fitted with two armoured turrets, each on the middle line and each fitted with two 25-ton muzzle-loading guns, having a powder charge of 70 lb. and a muzzle velocity of 1,210 ft.-sec.—less than half of what is now obtainable from our guns. Her displacement was 8,320 tons and her speed 15 knots; the displacement of our present Monarch is 22,500 tons and her speed 21 knots. She proved an excellent sea boat, and long remained on active service.

Sir Edward Reed displayed great ingenuity and resource in developing all-round fire by guns mounted on "end pivots" in the broadside fashion, but as experience accumulated this method of mounting guns for battleships was abandoned. The Devastation and Thunderer were soon after constructed, embodying the turret system of mounting. The former was floated out of dock at Portsmouth in July, 1871. She was the first iron vessel built in that yard. The Thunderer was launched at Pembroke in March, 1878. These vessels were designed by Sir Edward Reed, but completed under the supervision of his successor, Sir Nathaniel Barnaby. After the loss of the Captain, much controversy as to their seaworthiness took place in the public press. A powerful committee was formed to consider the design. Some slight alterations were made, and the committee reported that in their opinion the design as completed was quite satisfactory. I went to sea on the Devastation as the representative of Sir Nathaniel Barnaby, during the first cruises of the vessel, when she fully established her seaworthiness. These vessels were 285 ft. long, 62 ft. 2 in. in beam, and 9,300 tons displacement. They were fitted with two turrets, one at each end of the ship on the middle line, each carrying two 35-ton muzzle-loading guns, at that time jocularly called "Woolwich Infants," which were then the most powerful guns afloat. They had no sail spread and their decks were remarkable for the complete absence of obstructions to fire from the turret guns; the forward pair of guns could fire right ahead with an arc of training extending from many degrees abaft the beam on one side of the vessel to the same angle abaft the beam on the other side, and the after pair could fire right astern with an arc of training extending for many degrees before the beam on one side of the vessel to the same angle before the beam on the other side. They were the first ships with "all big-gun" armaments built for our Navy; they continued on active service for many years and proved so satisfactory that in their later days they were rearmed with 10-in. B.L. guns. The design was repeated with improvements in a Dreadnought of 1872.

The next stage in the advance towards our present fleet was the Inflexible, built at Portsmouth and completed in 1881. She was commanded by Captain (now Lord) Fisher at the Battle of Alexandria. She was designed by Sir Nathaniel Barnaby, and was also an "all big-gun" ship. She was rigged, and her dimensions were: Length 320 ft., beam 75 ft., displacement 11,400 tons. She was fitted with two turrets placed *en echelon*, one on each broadside on an armoured citadel at the middle of the vessel, and each carried two 80-ton muzzle-loading guns. All four guns could fire on either broadside and right ahead, one gun from each turret could fire right astern, and each pair of guns had an arc of training on its own side of the ship from right ahead to nearly right astern. She had no side armour at the forward and after ends of the water-line. The lower parts of the vessel at the ends were protected by a strong deck worked a few feet below the water-line. Inside the ends of the vessel thick walls of cork were fitted, to assist in preserving the buoyancy of the vessel when in action.

I had the advantage of being associated with Captain Fisher in completing and fitting the vessel. One difficulty in this vessel was her probable tendency to excessive rolling on account of her large metacentric height. Many devices were discussed. My proposal was to fit suitable tanks or "water chambers," for carrying free water for this purpose, which Captain Fisher agreed to. On trial these proved most effective. I also had the privilege of accompanying this vessel on her first cruise, as the representative of Sir Nathaniel Barnaby and for the purpose of testing the "water chambers." Much discussion took place in connection with the gunnery trials as to the relative values of the right ahead fire, the broadside fire and the arcs of training in the Devastation and Inflexible arrangements of armament. I left the Inflexible shortly before the bombardment of Alexandria. I took away with me an outline design which had been evolved during the cruise and which was described as a combination of the Devastation and Inflexible designs. The armament was an "all big-gun" armament of four pairs of 16-in. 80-ton guns mounted in turrets, all placed on the upper deck; one pair at each extremity of the vessel on the middle line as in the Devastation, and one pair placed on each broadside *en echelon* as in the Inflexible. Thus one pair of guns had direct ahead fire with an arc of training from well abaft the beam on the starboard side to well abaft the beam on the port side; one pair of guns had a direct astern fire with an arc of training from well before the beam on the starboard side to well before the beam on the port side; the pair of guns mounted in the starboard *en echelon* turret had an arc of training on the starboard beam from nearly right ahead to nearly right astern, and a considerable arc of training on the port beam, one gun of this turret also being capable of firing directly ahead and the other directly astern; the fourth pair of guns in the port *en echelon* turret had an arc of training on the port beam from nearly right ahead to nearly right astern and a considerable arc of training on the starboard beam, one gun of this turret also being capable of firing directly ahead and the other directly astern. Four big guns could always be brought to bear on any target right ahead or right astern or on either bow or on either quarter; and on the beam six big guns could always be brought to bear and sometimes eight on any target, and over a certain angle eight could be brought to bear. The scheme involved a displacement of 16,000 tons, and was considered inadmissible by Sir Nathaniel Barnaby on this account.

In all, five vessels were built in accordance with the main features of the Inflexible design; but the latter four, viz., Ajax, Agamemnon, Colossus and Edinburgh, were of smaller dimensions. Of these the Colossus and Edinburgh were the first battleships built of steel.

At this stage, upon the introduction of powerful rapid-firing 6-in. guns, it was considered desirable to associate the main armament of battleships with a secondary armament of such guns. Breech-loading guns of large calibre were also being constructed at this time; which made it practicable to load the guns from inside the turrets instead of from outside as was necessary with muzzle-loading guns; it, moreover, enabled them to be made of any length considered desirable for ballistic purposes. To give effect to these improvements, and especially the former, the Admiralty laid down the Collingwood at Pembroke, choosing the Devastation distribution of main armament as the more suitable for the introduction of the secondary armament. She was commenced in July, 1880, launched on November 22, 1882, and completed at Portsmouth in July, 1887. She was designed by Sir Nathaniel Barnaby. She was 325 ft. long, 65 ft. beam, and her mean draught was 26 ft. 6 in.; her displacement was 9,500 tons, her speed was 16½ knots, and she carried four 12-in. 43-ton B.L. guns, six 6-in. rapid-fire guns, four Nordenfeldt, and other small guns. A pair of 12-in guns was mounted on the middle line at each end of the ship, and the secondary armament was disposed along the sides of the vessel between them. She had an armour belt 18 in. thick amidships, over a portion of her length.

The design of this vessel met with adverse criticism on account of what was considered the small length (about 150 ft. out of 325 ft.) of armoured protection on the water-line, and its small height (about 1 ft. 6 in.) above water. The design, however, was repeated in all essential respects, but with increase in the power of the guns, in five other vessels, viz., Anson, Benbow, Camperdown, Howe, and Rodney. The Benbow was fitted with one 16·25-in. 111-ton B.L. gun in each barbette, and as regards armament was long looked upon with great favour. Having excellent sea-going qualities, all these vessels remained on the active list for many years, but were not called upon to undergo the ordeal of battle.

Although none of the vessels I have mentioned were in commission in our Battle Fleets in 1914, I have thought it well to make the above slight reference to them, as their designs constitute well-marked definite stages in the evolution of our present fleet. The Monarch, as being the first turret ship, having really good sea-going qualities; the Devastation as being a very successful mastless turret ship with great gun power, consisting of a pair of heavy guns in a turret at each end of the vessel uninterfered with by deck fittings; the Inflexible, a rigged turret ship with great gun power, consisting of a pair of heavy guns in a turret on each side of the vessel amidships, and with great armour protection; and the Collingwood, with her sisters, collectively known as the "Admiral" Class, as embodying in their armament the principle of four large breech-loading guns mounted in pairs at the two ends of the vessel, and having a powerful secondary armament of rapid-firing guns carried along the sides between these two pairs of guns.

Many improvements, particularly as regards armour protection, were made in succeeding vessels in designs prepared by Sir William White, some of which have been duly described in our Transactions. The feature of a main armament consisting of a pair of heavy guns at each end of the vessel, and a secondary armament wholly or mainly of 6-in. guns disposed in the space between them, was adhered to in battleships designed by him up to and including the "King Edward" Class. Many of these vessels, *e.g.*, the eight vessels of "King Edward VII" Class, viz., King Edward VII herself, and Hibernia, Africa, Britannia, Zealander, Hindustan, Dominion, and Commonwealth; the five vessels of the "Duncan" Class, viz., Duncan herself, and Cornwallis, Albemarle, Exmouth, and Russell, and a number of others were in our Commissioned Fleets in August, 1914.

After I became Director of Naval Construction in 1902, the design of the battleships for the 1903–4 programme came up for consideration. It was at length decided that they should have a powerful "all big-gun" armament of two calibres, viz., four 12-in. guns and twelve 9·2-in. guns. The design had been completed early in 1903, and approved; the first vessel, which was to be named Lord Nelson, had a pair of 12-in. guns in a gun-house at each end of the ship, and three pairs of 9·2-in. guns in gun-houses on each broadside between the 12-in. gun-houses; all on the upper deck. Later on, however, it was decided to postpone building from this design till the following year, and to build three additional King Edwards for the 1903–4 programme in order to complete the squadron of eight vessels of this type.

An "all big-gun" armament of single-calibre guns on the lines of the design evolved on the Inflexible had been considered at the same time with the Lord Nelson design, but the two-calibre armament was preferred and the design was not gone on with. Admiral Fisher, who was then Commander-in-Chief at Portsmouth, was, however, strongly in favour of the single-

* Paper read before the Institution of Naval Architects, April 9, 1919.

† There are given in the paper tables of dimensions of all ships built for the Navy up to 1914; but we regret that owing to pressure on our space we are not able to reproduce them.

calibre gun arrangement. In the Lord Nelson, as afterwards laid down in 1904–5, the condition that the vessels of this class should be capable of being docked in the existing docks at Chatham and Devonport, led to the reduction of the secondary armament to ten 9·2-in. guns instead of twelve 9·2-in. guns. In effecting this change the middle gun-house of the three 9·2-in. gun-houses on each beam was reduced in size and provided with a single 9·2-in. gun.

Only two vessels of the "Lord Nelson" type were built, the Lord Nelson herself and the Agamemnon. A note of these vessels is given in my paper of 1911, including a midship section (the shape of the section, as will be noticed, is approximately the shape of the Chatham dock, into which the vessels had to be capable of entering). They are 410 ft. long, 79½ ft. beam, 16,500 tons displacement, and 18½ knots speed. The gun-houses are protected by 8-in. and 7-in. armour, and the bases of the gun mountings by 8-in. armour. From the forward 12-in. gun position to the after 12-in. gun position the side armour is 12 in. thick in the vicinity of the water-line, and 8 in. above this to the height of the upper deck. Before and abaft the 12-in. gun position it does not rise to the upper deck, and tapers towards the extremities. In addition to the main armament there are twenty-four 12-pdr. anti-torpedo boat guns carried upon the superstructure, and a hurricane deck.

Admiral Sir John Fisher became First Sea Lord at the Admiralty in October, 1904. He brought with him from the Mediterranean (the "fishpond," as it was then called) several designs of warships, amongst them a design of an "all big-gun" battleship having six pairs of 12-in. guns all mounted on the middle line, three at each end of the vessel, in steps, one close behind another; so that six guns could fire directly ahead and six directly astern, those behind firing over those in front; and all 12 guns could fire on either broadside. The speed of the ship was 21 knots. Shortly afterwards, Lord Selborne, First Lord of the Admiralty, announced that the Board had appointed "a special Commission on Designs to assist them and the Director of Naval Construction in the consideration of certain questions to be submitted to it by the Board in connection with the features of the future designs of different types of ships."

Admiral Sir John Fisher was requested to preside over the committee, upon which the undermentioned naval officers and civilians were appointed to serve:—

Naval Officers.—Rear-Admiral H.S.H.. Prince Louis of Battenberg, G.C.B., G.C.V.O., A.D.C., Director of Naval Intelligence; Engineer Rear-Admiral Sir John Durston, K.C.B., Engineer-in-Chief of the Fleet; Rear-Admiral Alfred L. Winsloe, C.V.O., C.M.G., Commanding Torpedo and Submarine Flotillas; Captain Henry B. Jackson, R.N., F.R.S., about to assume the office of Controller; Captain John R. Jellicoe, C.B., R.N., about to assume the office of Director of Naval Ordnance; Captain Reginald H. S. Bacon, D.S.O., R.N., Naval Assistant to the First Sea Lord; Captain Charles E. Madden, M.V.O., R.N., about to assume the office of Naval Assistant to the Controller of the Navy.

Civilian Members.—Mr. Philip Watts, LL.D., D.Sc., F.R.S., Director of Naval Construction; the Right Hon. the Lord Kelvin, O.M., G.C.V.O.; Professor J. H. Biles, LL.D., Glasgow University; Sir John Thornycroft, F.R.S., D.C.L.; Mr. Alexander Gracie (Fairfield Shipbuilding Company); Mr. R. E. Froude, F.R.S., Superintendent of Admiralty Experimental Works; Mr. W. H. Gard, M.V.O., Chief Constructor of Portsmouth Dockyard.

The first meeting of the committee was fixed for January 3, 1905.

Subsequently, their lordships appointed Commander Wilfred Henderson to be secretary to the committee, and Mr. E. H. Mitchell, Assistant Constructor, to be assistant secretary.

The terms of reference for the committee were:—

"(1) The Board of Admiralty have decided on the leading features of five types of vessels and wish the committee to assist the Board with their advice upon each type. (2) It must be clearly understood that it is no part of the function or purpose of the committee to relieve the Director of Naval Construction of his official responsibility. (3) The committee is to consider itself an advisory body of great value to the Board of Admiralty in consequence of the large and varied experience of its members, whose association with the Board of Admiralty in the consideration of new types of vessels containing so many novel features will lend great weight to the decisions arrived at. (4) The distinctive characteristics of these five types which are to be considered by the committee are enumerated in the accompanying statement:—

"INSTRUCTIONS TO BE OBSERVED IN CONSIDERING THE FEATURES WHICH SHOULD BE INCORPORATED BY THE DIRECTOR OF NAVAL CONSTRUCTION IN THE NEW DESIGNS OF SHIPS.

"I. *Battleship.*—Speed, 21 knots. Armament, 12-in. guns and anti-torpedo craft guns. Nothing between. 12-in. guns to be as numerous as possible. No guns on main deck, except anti-torpedo craft guns; if necessary to place them there, armour to be adequate. The battleship must be capable of ample docking accommodation at Portsmouth, Devonport, Malta and Gibraltar, but the design will not be condemned for the sole reason that the ship cannot be docked at Chatham or pass through the lock there." Docking facilities to be carefully observed.

"II. *Armoured Cruisers.*—Speed, 25 knots. Armament, 12-in. guns and anti-torpedo craft guns. Nothing between. 12-in. guns to be as numerous only as is consistent with the above speed and reasonable proportions. Armour to be on similar scale to 'Minotaur' Class. Docking facilities to be carefully observed.

"III. *Torpedo Craft.*—Destroyers to be divided into two classes: (1) Ocean-going, (2) coastal service. The former to aim at a speed of 33 knots at war load in average weather, and be about 600 tons; the latter to aim at a speed of 25 knots and not to exceed 250 tons. In addition an experimental large ocean-going destroyer to be designed which will achieve 36 knots at war load in average weather."

Lord Fisher's twelve-gun battleship was very much discussed and very much liked. It was, indeed, similar in principle to the Collingwood design. Six guns were placed together at each end of the vessel (instead of only two as in Collingwood), and the centre portion of the ship was available for a secondary armament and other purposes. But it turned out that the size of the vessel would be very much greater than had been supposed in the Mediterranean and very much more costly than could be entertained by the Board of Admiralty. Besides which, it was not quite established that, in any case, it would be wise or economical to put as many as three pairs of guns together in steps at each end of the vessel; whereas, an exceedingly good ship could certainly be devised with two pairs of guns so placed. This could be protected with side armour to the height of the upper deck, as in the Lord Nelson, and the gun-houses and decks could be properly protected with armour. On working this out it was shown that even this would lead to a much bigger and more costly ship than could be adopted by the Board. It was, however, recognised that this was a type to be aimed at in the future.

The question was how nearly this design could be approached for the sum of money which could be allowed for the vessel. It was found that this could be done by bringing the two raised gun-houses, one forward and the other aft, down to the level of the upper deck, putting them one on each broadside, and making sundry other modifications, which practically brought the armament to that which had been devised on board the Inflexible in 1882 by combining the Devastation and Inflexible arrangements of armament. On further consideration it was decided that a fifth turret should be introduced on the middle line near the middle of the ship. It was found possible to do this by making certain changes and increasing the length of the ship, and the design of the Dreadnought was arrived at.

The principal features of the Dreadnought design (Parl. Paper, Cd. 3048 of 1906) are given in my paper of 1911. Her length is 490 ft., her breadth 82 ft., her displacement 17,900 tons, horse-power 23,000, and speed 21 knots. She has three pairs of guns on the centre line of the ship and two pairs mounted on the broadside opposite one another. Eight guns can be fired on either broadside, and four, or possibly six, 12-in. guns can be fired simultaneously ahead or astern. She also carries twenty-four 12-pdr. guns and has five 21-in. submerged torpedo tubes. Her armour belt is 11 in. thick amidships; the redoubts and gun-houses are 11 in. to 8 in. thick and the protective deck varies from 1½ in. to 2½ in. It is interesting to note that the weight of her armament, as increased by the weight of the fifth pair of guns, was exactly the same as the wieght of the Lord Nelson's armament as building with the reduced number of the 9·2-in. guns.

The Orion, laid down in 1909–10, five years after the Dreadnought, was the first vessel in which the scheme for an "all big-gun" battleship put forward by Lord Fisher in 1904 was fairly realised. The steps leading up to the Orion made in successive years were as follows:—

From the Dreadnought to the Bellerophon: Programme year 1906–7.
- Beam increased 6 in., viz., 82 ft. to 82 ft. 6 in.
- Displacement increased 700 tons—from 17,900 tons to 18,600 tons.
- Coal supply reduced 250 tons—from 2,900 tons to 2,650 tons.
- Belt armour modified from 11 in., 8 in., 6 in., 4 in., to 10 in., 9 in., 8 in., 7 in., 6 in., 5 in.
- Barbette armour modified from 11 in. and 4 in., to 9 in. and 5 in.
- Twelve 12-pdr. 18-cwt. guns replaced by sixteen 4-in. 50-calibre guns.
- Two after broadside submerged torpedo tubes removed, *i.e.*, 5 sub. T. became 3 sub. T.

From the Bellerophon to the St. Vincent: Programme year 1907–8.
- Length increased 10 ft.—490 ft. to 500 ft.
- Breadth increased 1 ft. 6 in.—82 ft. 6 in. to 84 ft.
- Displacement increased 650 tons, from 18,600 tons to 19,250 tons.
- Speed increased 0·25 knot, from 20·75 knots to 21 knots.
- Shaft horse-power increased 1,500, from 23,000 shaft horse-power to 24,500 shaft horse-power.
- Radius of action increased 1,180 miles, from 5,720 miles to 6,900 miles.
- 50-calibre 12-in. guns installed instead of 45-calibre.
- Two additional 4-in. guns fitted—16 increased to 18.

From the St. Vincent to the Neptune: Programme year 1908–9.
- Length increased 10 ft.—500 ft. to 510 ft.
- Breadth increased 1 ft.—84 ft. to 85 ft.
- Displacement increased 650 tons, from 19,250 tons to 19,900 tons.
- Shaft horse-power increased 500, from 24,500 shaft horse-power to 25,000 shaft horse-power.

In this vessel the two pairs of guns in turrets mounted on the broadside were placed *en echelon*, thus enabling both pairs to fire on either broadside; and the fifth turret was moved aft and placed on a barbette immediately on the fire side of the aftermost turret. Two very important developments.

The number of 4-in. guns was reduced to 16.

From Neptune to Colossus: Programme year 1909–10.
- Displacement increased 100 tons, from 19,900 tons to 20,000 tons.
- Bunker capacity increased 190 tons—2,710 tons becomes 2,900 tons.
- Radius of action increased 350 miles—6,330 miles becomes 6,680 miles.
- Belt armour 11 in., 8 in. and 7 in., as compared with 10 in., 8 in., 7 in., 2½ in.
- Barbette armour 11 in. to 4 in., as compared with 9 in. to 5 in.

From Colossus to Orion: Programme year 1909–10.
- Length increased 35 ft., from 510 ft. to 545 ft.
- Breadth increased 3½ ft., from 85 ft. to 88 ft. 6 in.
- Draught increased 6 in., from 27 ft. to 27 ft. 6 in.
- Displacement increased 2,500 tons, from 20,000 tons to 22,500 tons.
- Coal supply increased 400 tons, from 2,900 tons to 3,300 tons.
- Shaft horse-power increased 2,000, from 25,000 shaft horse-power to 27,000 shaft horse-power.
- Belt increased from 11 in., 8 in. and 7 in., to 12 in., 9 in. and 8 in.
- Side armour carried to the height of upper deck 8 in. thick.
- Barbette armour reduced from 11 in. to 10 in.
- Ten 13·5-in. guns mounted instead of ten 12-in. 50-calibre B.L. guns.
- Weight of broadside increased from 8,500 lb. to 12,500 lb.
- All of the turrets were placed on the centre line of ship; one of the *en echelon* turrets being placed on a barbette immediately behind the foremost turret, and the other in the position originally occupied by the "fifth turret."

The Orion has practically the displacement, distribution of armament, protection, &c., contemplated in the first design got out to meet the views of Lord Fisher on his becoming First Sea Lord.

Proceeding to note the advances made in the King George, Iron Duke and Queen Elizabeth, we have:—

From Orion to King George V: Programme year 1910–11.
- Length increased 10 ft., from 545 ft. to 555 ft.
- Breadth increased 6 in., from 88 ft. 6 in. to 89 ft.
- Displacement increased 500 tons, from 22,500 tons to 23,000 tons.
- Speed increased 0·7 knot, from 21 knots to 21·7 knots.
- Shaft horse-power increased 4,000, from 27,000 shaft horse-power to 31,000 shaft horse-power.
- Weight of broadside increased from 12,500 lb. to 14,000 lb. (heavier shell).

From King George V. to Iron Duke: Programme year 1911–12.
- Length increased 25 ft., from 555 ft. to 580 ft.
- Breadth increased 1 ft., from 89 ft. to 90 ft.
- Draught increased 6 in., from 27 ft. 6 in. to 28 ft.
- Displacement increased 2,000 tons, from 23,000 tons to 25,000 tons.
- Coal bunker capacity increased 380 tons, from 2,870 tons to 3,250 tons.
- Speed decreased 0·7 knot, from 21·7 knots to 21 knots.
- Shaft horse-power decreased 2,000, from 31,000 shaft horse-power to 29,000 shaft horse-power.
- Radius of action increased 1,500 miles, 6,280 miles to 7,780 miles.
- Battery for 6-in. guns (6-in. armour) on upper deck introduced.
- Sixteen 4-in. guns replaced by twelve 6-in. 45-calibre guns.
- Submerged torpedo tubes increased by 1, viz., 2 broadside and 1 stern to 4 broadside.

From Iron Duke to Queen Elizabeth: Programme year 1912–13.
- Length increased 20 ft., from 580 ft. to 600 ft.
- Breadth increased 6 in., from 90 ft. to 90 ft. 6 in.
- Draught increased 9 in., from 28 ft. to 28 ft. 9 in.
- Displacement increased 2,500 tons, from 25,000 tons to 27,500 tons.
- 3,250 tons coal plus 1,050 tons oil fuel in Iron Duke replaced by 3,400 tons of oil fuel in Queen Elizabeth.
- Speed increased 3½ knots, from 21½ knots to 25 knots.
- Shaft horse-power increased 46,000, from 29,000 shaft horse-power to 75,000 shaft horse-power.
- Belt increased from 12 in. to 4 in. to 13 in. to 6 in.
- Eight 15-in. 42-calibre guns mounted instead of ten 13·5-in. 45-calibre guns. This class was the first to carry 15-in. 42-calibre guns.
- Weight of main gun broadside increased from 14,000 lb. to 15,360 lb.
- Two more 6-in. guns fitted, viz., 12 became 14.

This class were the first battleships to be fitted with boilers for burning oil fuel only instead of coal. The "Queen Elizabeth" Class were the last Admiralty battleships for the designs and structural arrangements of which I am wholly responsible; but the Canada, purchased from Chili and completed after the war commenced, was built under my supervision. The detailed design was prepared by Mr. J. R. Perrett, of Elswick.

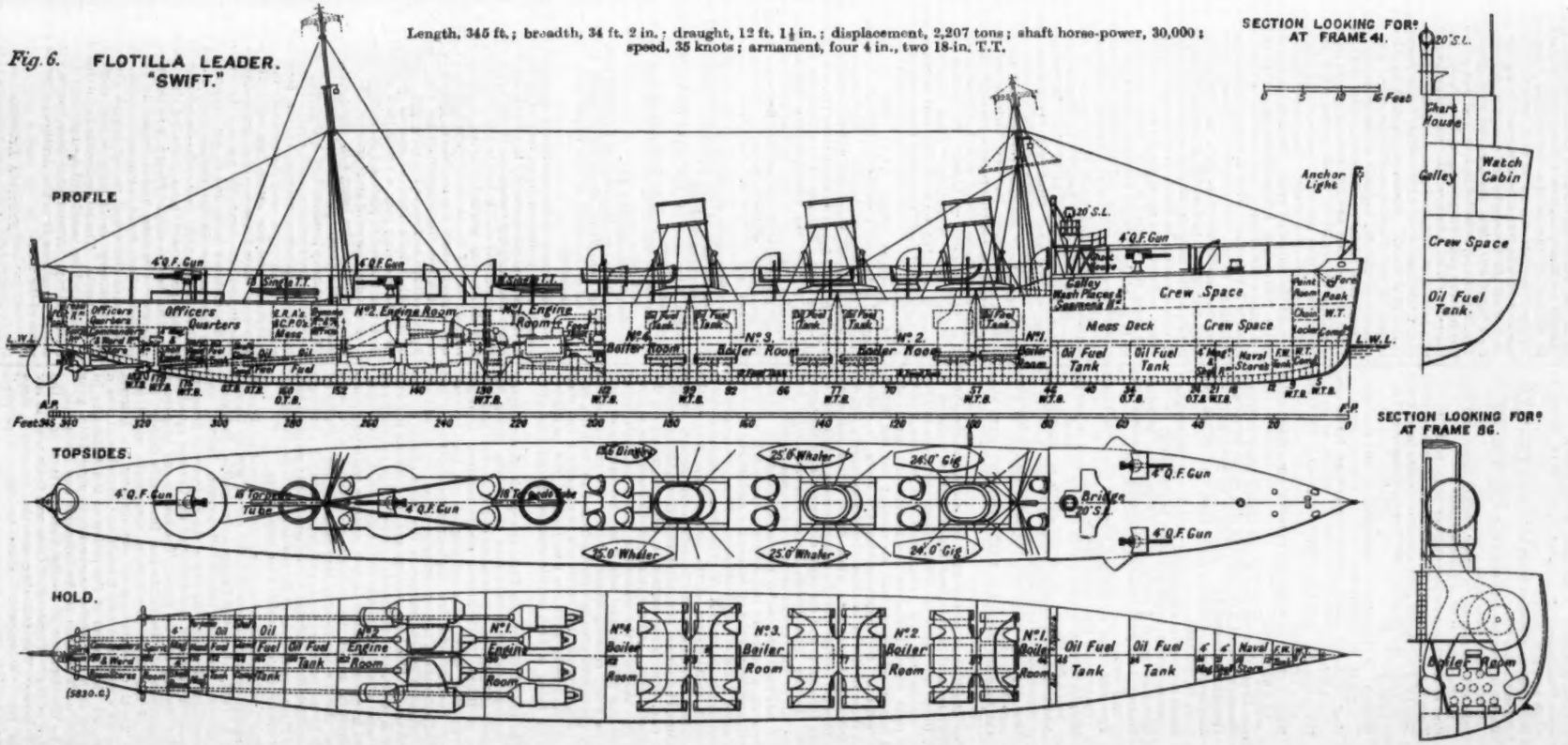
On Plates XLIII and XLIV are shown profile plans and sections of the Iron Duke and Queen Elizabeth.

All of the Dreadnoughts and Dreadnought cruisers have high forecastles and no bulwarks. The large number of big guns with large arcs of training carried by them made it difficult to find positions for a secondary armament. Down to and including the Colossus and Hercules the 12-in. guns carried on the broadside firing directly ahead reduces the forecastle to a narrow structure; in the "Orions" and more recent ships the forecastle extends to the side, and is more suitable for housing secondary armament. In the Dreadnought herself the biggest gun below the 12-in. guns was a 12-pdr. Other ships up to and including the "King George V" Class, carried sixteen 4-in. 50-calibre guns, excepting the 'St. Vincents," which carried twenty of these guns

HIS MAJESTY'S FLOTILLA LEADER.

Fig. 6. FLOTILLA LEADER. "SWIFT."

Length, 345 ft.; breadth, 34 ft. 2 in.; draught, 12 ft. 1¼ in.; displacement, 2,207 tons; shaft horse-power, 30,000; speed, 35 knots; armament, four 4 in., two 18-in. T.T.



in the Iron Duke and later ships, 6-in. 45-calibre guns have been carried as secondary armament. The position of these guns in the Iron Duke and Queen Elizabeth are shown on the Plates; they are under the forecastle as far aft as they could be got. Twelve were got into the Iron Duke, but Lord Jellicoe found that two of these could not be used.

The disposition of the main armament in the Iron Duke and Queen Elizabeth, and the arcs of training, are clearly shown on the Plates. The weight of the two 13·5-in. 45-calibre guns on the former ship is practically the same as the weight of the eight 15-in. 42-calibre guns of the latter. Thus there is a great increase in the right ahead and right astern fire in the Queen Elizabeth, as well as in the broadside fire; the weight of the projectiles fired in a broadside of the 15-in. guns of the Queen Elizabeth is 15,360 lb., whilst that of the 13·5-in. guns of the Iron Duke is only 14,000 lb.

The distribution and thicknesses of the armour are also shown on the Plates. The principal thicknesses in the Iron Duke being water-line belt 12 in., armour above 9 in. and 8 in., gun-houses 11 in., barbettes 10 in., conning tower 11 in. In the Queen Elizabeth the corresponding figures are: Water-line belt 13 in., plating above 6 in., gun-houses 13 in. and 11 in., barbettes 10 in., conning tower 11 in. In the Iron Duke the vertical protection plating below the lower deck is 1½ in., in the Queen Elizabeth it is 2 in.; the forecastle deck plating is 1 in. in both ships; the upper deck plating over the main portion is 2 in. in both ships; the middle deck plating is 2½ in. and 1 in. respectively in the two ships, and the lower plating 2½ in. and 3 in. respectively.

The machinery installation of the Iron Duke consists of two sets of Parsons marine steam turbines working four shafts, all four shafts being available for ahead and astern working. Each set consists of one high-pressure ahead and one high-pressure astern turbine on the wing shaft and one low-pressure ahead and one low-pressure astern in the same casing on the inner shaft, which work in series on the two shafts on the same side of the middle line of the vessel. When working at about 300 r.p.m. the aggregate power of the complete installation was estimated to realise 29,000 shaft horse-power, sufficient to give the vessel a speed of 21½ knots. On trial the vessel attained a speed of 21·6 knots when developing 30,040 shaft horse-power. The boiler installation consists of 18 Babcock and Wilcox water-tube boilers loaded to 235 lb. per square inch, arranged in three boiler rooms.

Bunker space is provided for 3,250 tons of coal, and 1,500 tons of oil fuel can be stowed in the double bottom, the total fuel being sufficient to give the vessel a radius of action of over 7,500 miles at 10 knots.

In the Queen Elizabeth the machinery consists of a four-shaft installation, also of Parsons marine steam turbines, two high-pressure ahead turbines and two high-pressure astern turbines directly coupled to the wing shafts, and two low-pressure ahead and two low-pressure astern turbines combined directly coupled to the inner shafts. In addition, two cruising turbines are geared to the wing shafts for use at cruising speeds. The revolutions at full power are 275 per minute. Twenty-four water-tube boilers, burning oil fuel only, installed in four boiler rooms and working at a pressure of 235 lb. per square inch, supply the requisite steam at a pressure of 170 lb. at the turbines. The designed power of the machinery was 56,000 shaft horse-power, sufficient to give the vessel a speed of 25 knots, these figures being considerably exceeded upon the trials of the various vessels of the class.

The building of a satisfactory vessel of the "Dreadnought" type such as is represented by the Orion, was not at first practicable owing to want of money. From time to time more money was placed at the disposal of the Board for the cost of new construction, and especially for the cost of individual ships of the "Dreadnought" Class. Starting from the programme year 1900–1, the amounts of money asked for in the Navy Estimates for new construction in each programme year were as under:—

	£	First Lord.	First Sea Lord.
1900–1 ...	8,460,146	Rt. Hon. G. J. Goschen	Lord Walter Kerr.
1901–2 ...	9,003,256	Lord Selborne	,,
1902–3 ...	9,058,520	,,	,,
1903–4 ...	10,136,430	,,	,,
1904–5 ...	11,654,176	,,	,,
1905–6 ...	9,566,002	Lord Selborne	Sir John Fisher.
1906–7 ...	9,235,000	Lord Tweedmouth	,,
1907–8 ...	8,100,000	,,	,,
1908–9 ...	7,545,202	,,	,,
1909–10 ...	8,885,194	Rt. Hon. R. McKenna	,,
1910–11 ...	15,279,830	,,	Sir A. Wilson.
1911–12 ...	15,063,877	,,	,,
1912–13 ...	13,971,527	Rt. Hon. W. S. Churchill	Sir F. Bridgeman.
1913–14 ...	13,276,400	,,	H.S.H. Prince Louis of Battenberg.
1914–15 ...	15,292,950	,,	,,

The Dreadnought herself was laid down in October, 1905. From that time onwards till 1908–9 it will be seen there was a steady drop in the total amount asked for as the yearly vote for new construction. From the year 1909–10 onwards there was an almost continuous rise in the amount of money Parliament was asked to vote for new construction. It was mainly in this latter period that the development of the later Dreadnoughts took place, on account of the greater amount of money available for the increase in the fighting qualities of this class of ship. Both the Orion and the Colossus were laid down in 1909–10. The Queen Elizabeth was completed

in the programme year 1914–15. The cost of these ships, therefore, had to be met mainly in the years 1909–10 to 1914–15. It will be seen that for 1911–12 Mr. McKenna obtained the sum of 15,063,877*l.* for new construction, which was a larger sum than any previous First Lord had obtained from Parliament. This record was again raised by Mr. Winston Churchill who framed his "Peace" Naval Estimates for 1914–15 on the basis of 15,282,950*l.* being required for new construction in that year.

All of the "Dreadnought" battleships and cruisers down to and including the Queen Elizabeth were carefully designed to be safe against the explosion of two torpedoes in any position. The subdivision is very carefully arranged, the main bulkheads being unpierced by water-tight doors, &c., to a height of 9 ft. above the water-line, and sufficient stability provided in each case to ensure the vessel not capsizing from loss of stability due to the flooding of compartments. The latter provision usually led to large metacentric height and a tendency to roll even with large bilge keels*; but it has been accepted as necessary for the safety of the vessels. Three Dreadnoughts have been seriously damaged by torpedoes and/or mines, but (assuming that the Audacious was finally lost from the action of the sea) they have withstood the attack.

In the case of the Marlborough, at 6.54 p.m. on May 31, 1916, she was torpedoed in the Jutland fight, but was able to fight on; commencing at 7.13 p.m., she fired 14 rapid salvoes at a ship of the "Konig" Class, which was seen (presumably as a result of these salvoes) to turn out of her line. It is true that later on the Marlborough got into difficulty by the continued entry of water and had to ease down in speed. She, however, arrived in the Humber at 8 a.m. on June 2, 37 hours after she had been torpedoed, and in the meantime had driven one of the Konigs out of the line of battle. She was afterwards taken to the Tyne for repairs, which were speedily effected; she subsequently joined the fleet, and now appears in our *Navy List* as an effective ship.

In dealing with our heavy losses at Jutland, Lord Jellicoe stated that our ships were inadequately protected by armour as compared with the German vessels of the battle cruiser type. Whether it is better to have greater gun-power or greater protection is a naval question, but it may well be the case that our superiority in gunfire was a very large and possibly dominant feature in bringing about the present naval position. Where there is equality of displacement and equal skill in designing, any difference in rival ships must necessarily involve some features in which each vessel is inferior to the other. Every Board of Admiralty has to consider this matter in the case of each new design and to decide upon the particulars of each feature to be embodied in it. Prior to the outbreak of the recent war the question when under review had to be decided mainly by the light of careful consideration of various possibilities, in which conjecture and reflection as distinct from actual hard-won experience was unavoidably the predominating element.

Lord Jellicoe very fairly mentions the superiority of the German shells used at Jutland over our own shells used in that action, and I wish to submit my opinion that our battle cruisers at Jutland suffered far more severely from the excellence of the German practice and of the German shells than they did from any relative thinness of armour in our ships in comparison with that of the German ships. It is probable that the German squadron had very exact information from their airships as to the nature of the forces advancing to meet them, together with the exact range long before they came in sight. Besides which it is possible that the Germans have gyroscopic control for fixing the elevation of their guns, which would have given them very great advantage in this particular engagement.

Evolution of the Cruiser Type.

The recent evolution of our cruisers has been along two distinct lines of progress. One line of progress led us to the battle-cruiser Tiger, the other to the Arethusa of the so-called light cruiser type. Both types have rendered excellent service during the war, and both types have suffered considerable losses.

The development of the battle-cruiser type from earlier cruisers down to and including the Lion and Princess Royal has been dealt with in my 1911 paper.

The particulars of the evolution step by step from the "Invincible" Class to the Tiger, are as follows:—

From the three Invincibles to the three Indefatigables.
- Length increased 25 ft., viz., 530 ft. to 555 ft.
- Beam increased 1 ft. 6 in., viz., 78 ft. 6 in. to 80 ft.
- Draught increased 6 in., viz., 26 ft. to 26 ft. 6 in.
- Displacement increased 1,550 tons, viz., 17,250 tons to 18,800 tons.
- Shaft horse-power increased 3,000, viz., 41,000 shaft horse-power to 44,000 shaft horse-power.
- Speed increased 0·30 knot, viz., 25·5 knots to 25·8 knots.
- Submerged torpedo tubes reduced from five 18-in. tubes (four broadside and one stern) in Invincible to two 18-in. tubes (broadside) in Indefatigable.
- Coal capacity increased 87 tons, viz., 3,083 tons to 3,170 tons.
- Oil capacity increased 130 tons, viz., 710 tons to 840 tons.

From the three Indefatigables to the Lion, Princess Royal and Queen Mary.
- Length increased 105 ft., viz., 555 ft. to 660 ft.
- Beam increased 8 ft. 6 in., viz., 80 ft. to 88 ft. 6 in.
- Draught increased 1 ft. 6 in., viz., 26 ft. 6 in. to 28 ft.
- Displacement increased 7,550 tons, viz., 18,800 tons to 26,350 tons.
- Shaft horse-power increased 26,000, viz., 44,000 shaft horse-power to 70,000 shaft horse-power.
- Speed increased 2·2 knots, viz., 25·8 knots to 28 knots.
- Belt armour modified from 6 in., 5 in., 4 in., to 9 in., 6 in., 5 in., 4 in.
- Barbette armour modified from 7 in., 4 in., 3 in., to 9 in., 8 in., 4 in., 3 in.
- Side armour carried to upper deck in Lion, and only to the main deck in Indefatigable.
- Size of torpedoes increased from 18 in. to 21 in.
- Turret guns increased from 12-in. to 13·5-in. calibre.
- The 13·5-in. turret guns are all on centre line of ship in Lion, the guns in "B" turret firing over "A" turret.
- Weight of broadside increased 3,200 lb., viz., 7,296 lb. to 10,496 lb.
- Coal capacity increased 330 tons, viz., 3,170 tons to 3,500 tons.
- Oil capacity increased 295 tons, viz., 840 tons to 1,135 tons.
- Radius of action reduced 720 miles, viz., 6,330 miles to 5,610 miles.

From Lion, Princess Royal and Queen Mary to Tiger.
- Beam increased 2 ft., viz., 88 ft. 6 in. to 90 ft. 6 in.
- Draught increased 6 in., viz., 28 ft. to 28 ft. 6 in.
- Displacement increased 2,150 tons, viz., 26,350 tons to 28,500 tons.
- Shaft horse-power increased 38,000, viz., 70,000 shaft horse-power to 108,000 shaft horse-power.
- Speed increased 2 knots, viz., 28 knots to 30 knots.
- Sixteen 4-in. guns on Lion increased to twelve 6-in. on Tiger.
- Two additional submerged torpedo tubes on Tiger, viz., two to four (broadside).
- Weight of broadside increased 704 lb., viz., 10,496 lb. to 11,200 lb.
- Additional 3-in. armour belt, 3 ft. 9 in. deep below water-line belt on Tiger.
- Coal capacity decreased 180 tons, viz., 3,500 tons to 3,320 tons.
- Oil capacity increased 2,345 tons, viz., 1,135 tons to 3,480 tons.

The distribution of the main armament in the three Invincibles and in the three Indefatigables is shown in Fig. 10, of my paper of 1911. They have four turrets, each containing two 12-in. guns, one on the middle line right forward, one on the middle line right aft, and one *en echelon* on each broadside; but the broadside guns of the Indefatigables are more *en echelon* than those of the Invincibles, thereby increasing the arc of training of the guns when firing across the deck. The forward turrets and the two *en echelon* turrets are on a long forecastle, and the right aft turret is on the upper deck. In the Lion, Queen Mary, Princess Royal and Tiger, all of the turrets are placed on the middle line, which has been effected by placing one of the *en echelon* turrets on a barbette immediately abaft the foremost turret, and moving the other into the middle line in about the same position longitudinally. The arrangement is shown clearly on Plate XLV. The same long forecastle is retained, enabling ten of the twelve 6-in. guns of the secondary armament to be efficiently housed on an armoured battery of 5-in. and 6-in. armour, the remaining two 6-in. guns being carried in 6-in. casemates on the forecastle deck. All the principal thicknesses of armour are also shown; the water-line belt 9 in., belt below water-line 3 in., upper belt 6 in., barbettes and gun-houses 9 in., conning tower 12 in.; the various decks have protective plating varying from 3 in. to 1 in., and the vertical protective bulkheads to magazines and shell rooms vary from 2½ in. to 1 in.; all of the protective plating being of high tensile steel of special protective quality.

The machinery of the Tiger is capable of developing an aggregate shaft horse-power of 108,000, giving her a speed of 30 knots. It consists of a four-shaft installation of Brown-Curtis marine steam turbines, arranged in two sets, each set consisting of one high-pressure ahead turbine and one high-pressure astern turbine on the inner shaft, one low-pressure ahead turbine and one low-pressure astern turbine in the same casing on the outer shaft. The high-pressure and low-pressure turbines work in series, and are directly coupled to the two shafts on the same side of the middle line of the vessel. The boilers, 39 in number, installed in five separate watertight compartments, are of the Babcock and Wilcox water-tube type, the furnace fronts being arranged for burning oil fuel in conjunction with coal when desired. Stowage is provided for 3,320 tons of coal and 3,480 tons of oil fuel. The Tiger was the last of the battle cruisers for the design and construction of which I am responsible.

The first occasion when our "Dreadnought" type of armament was in action with the enemy was on December 8, 1914, when the Canopus, Invincible, Inflexible, Carnarvon, Cornwall, Kent, Gloucester, Bristol, and Macedonia, all under the flag of Sir F. Doveton Sturdee, successfully engaged and destroyed the German squadron under the flag of Von Spee. The heavy and long-range armament of the Inflexible and Invincible decided the issue of the day. The victory completely wiped out the naval consequences of the disaster to Admiral Cradock's squadron and himself at Coronel, and was a complete vindication of the policy of the Admiralty in putting such a powerful armament as eight 12-in. guns in such swift cruisers as the Inflexible and Invincible.

The development of the light cruiser type up to the design of the "Weymouth" Class was dealt with in my 1911 paper. The following are the successive steps from the "Weymouth" Class to the "Arethusa" Class:—

The Weymouth was laid down in 1910. She had a length of 430 ft. between perpendiculars, a breadth of 48 ft. 6 in., a draught of 15 ft. 6 in., and a displacement of 5,250 tons. Her armament consists of eight 6-in. 50-calibre guns, four 3-pdr. guns, and two 21-in. submerged broadside torpedo tubes. One of the 6-in. guns is carried on the middle line on the forecastle right forward, two are carried on each broadside on the forecastle deck amidships, one on each broadside on upper deck abaft the forecastle, and one on middle line on upper deck right aft. She has a nickel steel protective deck 2 in. amidships, reduced to 1 in. and ½ in. at ends; over the steering gear the plating is 2 in. thick; her conning tower is of 6-in. armour. Her machinery, which consists of a four-shaft installation of compound reaction marine steam turbines, is of 22,000 shaft horse-power, and her speed 25·6 knots. Steam is supplied by 12 watertube boilers of the Yarrow small-tube type, with a steam pressure of 235 lb., capable of burning either coal alone or coal and oil in combination. Her fuel capacity is 1,290 tons of coal and 260 tons of oil, giving the vessel a radius of action of 5,610 miles when steaming at 10 knots. There are four vessels of this class.

The nine vessels of the "Chatham" Class were commenced the following year. They are of the same length as the Weymouth, 1 ft. more beam; seven of them had a displacement of 5,400 tons, and two of them a displacement of 5,440 tons. Five of these vessels have the same armament as the "Weymouth" Class; three of them have one additional 6-in. gun, and one of them has an extra 3-in. gun. In this class a marked advance was made in protective material carried on the sides, which consists of nickel steel 2 in. thick over the main portion of the vessel, reduced to 1 in. at the forward extremity, so that the total side plating is 3 in. thick amidships, reduced to 1½ in. at the forward extremity and 1½ in. at the after extremity. The nickel plating extended from 2 ft. 7 in. below the water-line to the upper deck over the machinery spaces. Before and abaft these spaces it extended to 3 ft. below the upper deck. The vessels had a conning tower of 6-in. armour as in the "Weymouth" Class. These vessels were fitted with twin-screw propellers driven by turbines of the impulse reaction type, there being one ahead reaction turbine, one ahead impulse turbine, one astern reaction turbine and one astern impulse turbine combined upon each shaft. The power was 25,000 shaft horse-power, and the speed attained varied from 25¼ knots to 26 knots. The boilers were similar to those in the "Weymouth" Class; and with a bunker capacity of 1,165 tons of coal and stowage space for 250 tons of oil fuel the vessels had a radius of action of 4,680 miles.

The Arethusa (Plate XLVI) was commissioned in August, 1914, and went into action within three days of leaving the builders' hands. Her length was 410 ft. between perpendiculars and 436 ft. overall; her breadth was 39 ft.; her depth moulded was 23 ft. 7 in. Her draught of water to the designed normal line was 13 ft. forward and 14 ft. aft, the corresponding displacement being 3,500 tons. As will be seen she had a forecastle extending to her forward boiler room, the freeboard being 21 ft. Her armament, which is shown on the profile and plan, consisted of:—

- Two 6-in. guns mounted on the middle line of the vessel, one on the forecastle forward and one on the upper deck aft.
- Six 4-in. guns on the upper deck; three on each broadside.
- One 4-in. high-angle anti-aircraft gun on the upper deck aft.
- One 3-pdr. saluting gun.
- One 0·303-in. Maxim boat and field gun.
- Four twin 21-in. above-water centre pivot torpedo tubes mounted on the upper deck, two on each broadside.

For the length of the machinery space the sides of the vessel were protected by a belt of protective plating, having a total thickness of 3 in., extending from 2 ft. 6 in. below the designed water-line to the upper deck. From the forward end of this belt to the stem a belt of slightly less depth was worked, having a thickness of 2½ in. reduced to 1½ in. at the forward end. A similar belt was worked abaft the machinery spaces to the forward end of the steering compartments, the thickness being 2½ in. reduced to 2 in. at the after end. This plating was of a high tensile steel of special protective quality. Over the steering gear a turtle-back shaped protective deck was worked of plating 1 in. in thickness.

A conning tower of steel armour was mounted on the forecastle, the sides being 6 in. thick and the roof 2½ in. thick. The communication tube had a thickness of 4 in. The machinery consisted of a four-shaft installation of marine steam turbines, each shaft being coupled direct to an independent turbine of the combined impulse and re-action type, each independent unit consisting of one ahead and one astern turbine in the same casing. The total shaft horse-power of the complete installation was 40,000, at about 590 r.p.m., the working pressure at the turbines being 185 lb. per square inch. She was the first cruiser in the British Navy to be fitted with boilers burning oil fuel only—machinery of this type having previously been installed in destroyers and torpedo boats only. Steam was supplied by eight separate water-tube boilers loaded to 236 lb. pressure per square inch, fitted in two boiler rooms. The designed speed with the vessel at her normal displacement and the machinery developing 40,000 shaft horse-power, was 30 knots. The oil-fuel tanks had a capacity of about 810 tons. The vessel had a single tripod mast carrying a control top. A number of these vessels were built with slight variations from the Arethusa after the commencement of the war.

Flotilla Leaders.

The Swift referred to in the author's 1911 paper as a destroyer of special type was the precursor of a group

* The question of fitting anti-rolling tanks in the Dreadnought herself was considered, but it would have led to a larger ship, and could not be allowed.

of similar vessels whose functions are indicated by the name "Flotilla Leaders," since given to them. Profile and plans of the Swift are given on page 583. She was built by Messrs. Cammell, Laird and Co., and completed in 1910. Her length between perpendiculars is 345 ft., length overall 352 ft. 11 in., breadth 34 ft. 2 in., depth moulded 21 ft. 6 in., displacement at a mean draught of 12 ft. 1¼ in. is 2,207 tons. The armament consists of: Four 4-in. 40-calibre 26-cwt. Q.F. guns, two mounted on the forecastle, one on the middle line on the engine-room casing, and one on a raised platform on the centre line of the vessel at the after end of the upper deck; two 18-in. centre pivot torpedo tubes mounted on the centre line of the upper deck, one over the forward engine-room and one just aft of the after engine-room. The designed speed was 35 knots, the designed power of the machinery being 30,000 shaft horse-power. She had four shafts driven by Parsons marine steam turbines arranged in two engine rooms. The steam generating plant consists of 12 boilers of the Laird Yarrow type, fitted for burning oil fuel only, and arranged in four boiler rooms. The oil-fuel tanks for use in war-time have a capacity of 282 tons, whilst 103 tons additional fuel can be carried in the peace tanks. The radius of action at full power is 395 miles, and at 15 knots 2,335 miles. The complement consists of 130 officers and men. In addition to the Swift, four vessels of closely similar dimensions and somewhat less power, but with six 4-in. guns instead of four, had been laid down by Messrs. J. S. White and Co. for the Chilian Government under my supervision, and were purchased by the Admiralty on the outbreak of war.

Destroyers.

The 20 destroyers referred to in the author's paper read before this Institution in 1911 form what is now known as the "I" Class. As will be seen from the tables appended to the present paper they are of the same dimensions and carry the same armament as the "Acorn" Class immediately preceding them, and are generally of the same speed. In six of them, however, propelling machinery of 15,500 shaft horse-power to 16,500 shaft horse-power was installed, giving to these vessels a maximum speed of 28 knots to 30 knots, as compared with 27 knots for the class generally. Three additional vessels of this class, forming part of the 1910–11 programme, but not laid down until July, 1911, were made 15 ft. longer than the rest, and Parsons turbines, having a total shaft horse-power of 20,000 on two shafts, were installed, giving a further increase of speed to about 32 knots, or 5 knots more than that of the majority of the vessels of the class.

In 1911–12, 20 destroyers of what is now known as the "K" Class were laid down from Admiralty designs. The length and displacement of these vessels are considerably greater than those of the "I" Class, permitting an increase of 50 per cent. or more in power of the propelling machinery with the consequent increase in speed, and of the substitution of a 4-in. gun for the two 12-pdr. guns carried in the previous vessels. One of these vessels, the Hardy, built by Messrs. Thornycroft, has a Diesel engine installation for cruising at low speeds, in addition to the Parsons steam turbines used for high powers, an experiment the result of which will be awaited with interest by those concerned in the development of the internal-combustion engine for ship propulsion.

In 1912–13, 18 destroyers of the "L" Class were laid down; they are practically the same as the "K" Class, except for the addition to the armament of two torpedo tubes and a 2-pdr. pom-pom. They are all twin-screw vessels, and two are fitted with geared turbines permitting a considerable reduction in the rate of revolution of the propellers and a gain in propeller efficiency.

In 1913–14, 13 destroyers of the "M" Class, of which six were designed by the Admiralty, and the remainder by the builders, were laid down before the commencement of the war. The difference from the "L" Class is slight, most of these vessels being 5 ft. longer, and there is an increase of propulsive power accompanied by a reversion in the case of 8 of the 13 vessels to triple screws. The principal dimensions of the "M" Class torpedo boat destroyer are as follow: length between perpendiculars, 265 ft., overall 273 ft. 4 in., breadth moulded, 26 ft. 8 in., depth moulded 16 ft. 3 in. The displacement at a mean draught of 9 ft. 3 in. is 1,008 tons.

The armament consists of: Three 4-in. 40-calibre Q.F. guns, all mounted on the centre line of the vessel, one forward on the forecastle, one amidships between the funnels, and one on the upper deck aft; two 2-pdr. pom-poms, one on each side at the after end of forecastle, and four 21-in. torpedo tubes, twin-mounted on centre-pivot mounts on the centre line of the vessel over the engine-room.

The propelling machinery, capable of developing 25,000 shaft horse-power, consists of a three-shaft installation of Parsons marine turbines. The high-pressure turbine is coupled direct to the centre shaft and exhausts into two low-pressure turbines, each of which is direct coupled to a wing shaft. A high-pressure cruising turbine is coupled by means of a clutch and suitable gearing to the forward end of the low-pressure turbine on the port shaft, and an intermediate-pressure cruising turbine is similarly fitted on the starboard shaft. These high and low pressure cruising turbines are arranged to work in series. An astern turbine is incorporated in each low-pressure turbine casing. When working at full power the main turbines run at about 750 r.p.m., the power generated being sufficient to maintain a speed of 34 knots when the vessel is in the normal condition. The boilers are of the Yarrow water-tube type, three in number, having a working steam pressure of 250 lb. per square inch, fitted for burning oil fuel only. They are installed in two separate boiler rooms, two in the forward room and one in the after room; the uptakes from each boiler leading into a separate funnel. The capacity of the oil-fuel tanks for use in war-time is 248 tons, whilst an additional 33 tons can be carried in the peace tanks. The radius of action of the vessel is 580 miles at full speed and 2,240 miles at 15 knots. The complement consists of 76 officers and men. No class of vessel has seen harder service or has been more indispensable than the destroyer during the war; the casualty list has been very heavy, and many of the vessels comprised in the numbers given above, which refer to the construction programmes, are no longer existing.

Submarines.

In the author's paper read before this Institution in 1911 an account was given of the British submarine boats up to and including the "C" Class, while the existence of the "D" Class was mentioned, though the particulars of these vessels at that time were kept secret. In these a more radical departure from the parent Holland type of submarine was made than in the "A," "B," and "C" Class boats, the shape of the hull being quite different, consequent on the introduction of external main ballast tanks, the adoption of twin screws driven by vertical four-cycle Diesel engines instead of the single-screw driven by horizontal petrol engines in the previous boats, the disposition of the two bow torpedo tubes vertically instead of horizontally and the provision of a stern torpedo tube. These departures from the previous type were made with the objects of increasing the endurance of the boats at sea and of eliminating the risks attending the use of gasolene. The external tanks enabled the reserve of buoyancy to be increased from the 10 per cent. or less of the previous boats to 25 per cent., thus rendering the boats less liable to founder suddenly in case of collision or similar accident and making them more habitable at sea. Although habitability and safety could have been increased by greater increase of reserve of buoyancy, it was considered undesirable to incur the great complication and bulk of flooding and venting apparatus necessary to deal with the ballast water representing reserve of buoyancy with the rapidity which is essential for the efficiency of any submarine boat. The economies effected by the improved conditions of propulsion at the surface and the greater quantity of fuel carried gave the "D" Class a radius of action at 11½ knots, about 25 per cent. greater than that of the "C" Class at 9 knots, but their most important advantage was their improved habitability, as the radius of action of the "C" Class boats calculated from their power, speed and fuel supply was already greater than the power of the crew to endure as a matter of routine the confinement and discomforts of existence at sea in these small boats in bad weather. The vertical arrangement of the bow torpedo tubes enabled the resistance to propulsion of the vessel to be somewhat reduced as compared with the horizontal disposition of tubes, and the addition of the stern torpedo tube was an experiment rendered possible by the increased size and altered shape of the vessel as compared with the "C" Class.

A 12-pdr. on a mounting housed inside the superstructure which was operated by compressed air so as to pass rapidly from the firing to the housing position was installed on submarine "D 4," and is believed to furnish the first instance of the mounting of artillery on a submarine boat. The gun and mounting were not enclosed in a watertight casing, and were thus exposed to the sea water whenever the boat dived. Considerable doubt was felt at the time of this experimental installation whether the delicate mechanism would long survive this treatment, but experience appears to have shown that effective measures can be taken to prevent undue corrosion and deterioration even under these adverse conditions. The provision of torpedo tubes firing on the broadside was also considered in the "D" design, and had some influence on the shape of hull adopted; but it would have been necessary to increase the size of the vessel in order to install such tubes, and at the time financial considerations prevented the acceptance of any more costly submarine than the "D" design.

A demand for broadside torpedo tubes co-existing with a determination not to accept any form of discharging frame such as the French used outside the boat, and inaccessible in the submerged condition, had always existed in the submarine service, and became more insistent as the boats increased in size, on account of the danger of collision with the target ship or other following in line, after firing a torpedo from a bow tube at short range. Two broadside torpedo tubes, one firing on each beam, were introduced in the "E" Class submarines of the 1910-11 programme, and were the chief cause of the difference in dimensions between this class and "D" Class. The increased size had, of course, its natural concomitant in increased power, speed, habitability and radius of action. At the time of the design of the "E" Class, opinion in the submarine service was so strongly against bow torpedo tubes that the omission of such tubes altogether in this design was seriously considered, and ultimately one tube only was fitted in the first vessels of the class, though the two tubes were reintroduced on the "E" Class design of 1911–12, without increase of dimensions, as it was found that the weight saved in the estimates for the first design permitted this to be done. In the "E" Class design a system of watertight subdivision of the main hull by transverse bulkheads was introduced for the first time in British submarines, thus increasing the safety of the boats in the case of accident, and greatly increasing the strength of the hull against external pressure.

Previously to this design the small size of the boats and the undesirability of isolating from their officers the men controlling the operations, vital in an emergency, of flooding and emptying ballast tanks, had prevented the subdivision of the main working space by watertight bulkheads, although for other reasons this course was obviously desirable.

These vessels, like previous British boats, had been designed with sufficient strength of hull to have a reasonable factor of safety at a depth of 100 ft., beyond which it was considered that a submarine would never descend voluntarily. The events of the war have shown that 100 ft. was an inadequate depth for which to design submarine boats, and it is fortunate that these very strong and heavy transverse bulkheads, which were not taken into account in the strength of hull calculations, were in existence.

The "E" Class submarines have formed the most important part of our submarine flotilla during the war, and the reports of their efficiency and of their ability to stand the rough usage of active war service have been very satisfactory.

In addition to the boats referred to above, which may be considered to be in the main line of development of British submarines, mention should be made of "S 1," designed by Messrs. Scott and Co., of Greenock, the "V" Class, by Messrs. Vickers, and the "W" Class, by Messrs. Armstrong, Whitworth and Co., Limited.

The design of "S 1" was based on that of the submarines previously built by the Fiat San Giorgio Company of Spezia, for the Italian and other Governments, though very much larger than any other boat built to this design at that date. This vessel is chiefly interesting from her size, and from the fact that on account of the high surface speed aimed at, steam propelling machinery was adopted for the first time in any British submarine, internal-combustion engines of the power required being in the experimental stage at that time. The "V" Class are remarkable boats from the high surface and submerged speeds, and the high reserve of buoyancy aimed at in the design on comparatively small dimensions. The designs of the "W" Class are based on that of the French submersibles of the "Pluviose" Class, as modified by their designer, Mons. Laubeuf, in his subsequent association with Messrs. Schneider et Cie, of Creusot. These vessels are remarkable for the ingenuity of their double hull construction, their unusually excellent control when diving, which has been obtained as the result of scientific experiments carried out with all types of submarines in the French Navy for a considerable period, and for the technical excellence and practical efficiency of all detailed designs in connection with their flooding, venting, electrical, and subsidiary installations. They are particularly interesting from the fact that the German submarines, which have been so efficient and so infamous during the war, were copied originally from the earlier Laubeuf design, and clearly show their parentage even in their latest and largest development.

The four boats of the "W" Class were transferred by the Admiralty shortly after their completion to our Italian Allies, and have rendered striking services during the war. At the commencement of the war, Great Britain and her Allies had:—

- 165 battleships and battle cruisers against 66 possessed by Germany and Austria.
- 240 light cruisers against 78 possessed by Germany and Austria.
- 853 flotilla leaders, destroyers and torpedo boats against 462 possessed by Germany and Austria.
- 105 sloops and gunboats against 29 possessed by Germany and Austria, and
- 248 submarines against 59 possessed by Germany and Austria.

The total number of ships possessed by Britain and her Allies was 1,611 against 694 owned by Germany and Austria. The total displacement of the ships of Britain and her Allies was 5,407,008 tons, against 1,715,936 tons of Germany and Austria. Britain and her Allies carried 1,497 guns of 8-in. calibre and upwards—Germany and Austria only 577, and so on for smaller guns and torpedo tubes. The total number of men carried by the ships of Britain and her Allies was 322,273—the total number of men carried by Germany and Austria was only 118,910.

Action of Ultraviolet Rays on Tropical Fruit.—It is rather curious that in a tropical climate like that of the Sandwich Islands attempts should be made to intensify the action of the sun rays by means of ultra-violet rays. Such experiments are, however, described by T. Tsuji in the *Louisiana Planter and Sugar Manufacturer*, vol. lx, No. 26, and he is not the first experimenter in that line. He observed that sugar-canes, which had been kept in the dark and had remained pale, turned green in the light of a quartz-mercury lamp within 2½ hours, in which period sun light had no effect. Grown in sunlight sugar-cane contained 30 per cent. more sugar than when grown in sunlight deprived of its ultraviolet rays by coloured glass screens; and when ultraviolet rays were added to the sunlight, the sugar yield was further raised by 8 per cent. Pineapples and bananas were matured and improved by being periodically exposed to ultraviolet rays, and the same rays also made it possible to keep cut leaves and stalks of bananas fresh in appearance under water for two weeks. That looks promising for the preservation of exported fruit; but as the ripening is also hastened, a caution has naturally to be added as to the intensity and duration of the treatment. The abstract of the paper quoted in *The Chemical News* of March 7, also alludes to experiments made to obtain ultraviolet rays from arc lamps, the carbons of which were impregnated with salts of the heavy metals (tungsten, molybdenum, titanium, uranium). We might remark that the vapour arc of an ordinary carbon lamp contains ultraviolet rays which can be concentrated by reflection; but inexpensive lamps for ultraviolet rays might find varied applications.

PHYSICAL SOCIETY OF LONDON.

AT the meeting of the Physical Society of London, held on Friday, March 14, 1919, at the Imperial College of Science, Professor C. H. Lees, F.R.S., president, in the chair, a paper, on "*Some Characteristics of the Spark Discharge and its Effect in Igniting Explosive Mixtures*," by Messrs. C. C. Paterson and Norman Campbell, was read by the former.

The object of the investigation was to determine the relation between the electrical characteristic of a spark discharge and its power of igniting explosive mixtures. The results show that the igniting power of a spark increases with both the capacity discharging and the spark potential, and that the energy required for ignition decreases rapidly as the spark potential increases. Various other properties of sparks are described.

Discussion.—Dr. Eccles said that, apart from the conclusions arrived at, there was a great deal to be learnt from the paper. The ingenious arrangements in the diagram of apparatus included, for example, a thermionic valve used as a limiting device. It seemed worth while emphasising that these thermionic vacuum tubes were going to be invaluable as variable resistances in investigations in all branches of physics. The use of these tubes assisted in the present research in eliminating the oscillatory discharge of the condenser through the spark-gap. This, in fact, appeared to be a principal difference between the operation of the present apparatus and that of a magneto and sparking plug as ordinarily used, for it is incredible that the magneto discharge takes place without oscillations; the capacity and inductance of the leads themselves will ensure the presence of oscillations of high frequency, which may have a bearing upon the time taken to convert the initial electrical energy into heat energy in the spark-gap.

Turning to the question of the ignition of gaseous mixtures, what is required in a spark, whether electrical or from flint and steel, is that a quantity of heat should be given to a small mass of matter in such a way that the temperature reached is sufficient to inflame the mixture round it. This in its turn must develop heat by combustion so fast that the next layer of mixture shall reach the temperature of ignition. If the process proves to be "catching," the wave of inflammation will spread through the whole mass catastrophically. Evidently, for the success of this process, it is necessary that the heat shall be deposited more quickly than the thermal conductivity of the surrounding matter can carry it away, and therefore a given small quantity of heat is the more effective the smaller the time and the mass in which it is developed and the lower the thermal conductivity of the medium. From this point of view it is, therefore, extremely surprising to hear that magneto makers have aimed at increasing the energy per spark. The speaker would like to ask if the authors consider their experiments, which were likewise against the joules per spark point of view, accorded better with the simple aspect of the matter just outlined.

Mr. E. H. Rayner said that from the diagram he thought the upper condenser could be made to give an oscillatory spark if required. In the case of plug sparking, the rate of rise of potential was as important as the actual voltage reached because of leakage.

Professor Lees asked if the authors had formed any conclusion as to the mechanism by which the ignition is produced. The importance of the potential seemed to indicate that it was the speed of the electrons that mattered.

The authors, in reply to Dr. Eccles' remarks, communicated the following: The thermionic valve does not damp out the oscillations in the condenser which discharges through the gap; it only prevents certain other condensers discharging through the gap. There was distinct evidence that the discharge was oscillatory—at any rate, when the discharging condenser and the spark potential exceeded certain limits. The single sparks mentioned in the paper doubtless often consisted of many oscillations; but these oscillations could not be separated, partly because their frequency was so great, partly because of the difficulties to which reference was made in stopping the discharge once it has started.

In the discharge produced by a magneto there are oscillations of two kinds. First, oscillations of the spark-gap circuit only, during which the terminals of the magneto act as free ends of the circuit; the frequency of these oscillations is probably (according to experiments by Mr. Albert Campbell and Mr. Dye) about 10^8; these oscillations are all contained in the single spark investigated in section 8, and are of the same nature as those which would occur if a suitable charged condenser were substituted for the magneto. Secondly, there are oscillations of the circuit which includes the spark-gap and the secondary of the magneto; the frequency of these oscillations is usually between 1,000 and 10,000. They give rise to the successive sparks, each probably involving oscillations of the first kind, which are seen when the discharge is viewed with a revolving mirror or the rotary spark-gap.

Dr. Eccles is doubtless correct in dividing the process of ignition into two stages, in the first of which combustion is initiated, in the second of which it is propagated throughout the mixture. In the second stage the process is undoubtedly thermal. Our experiments are not sufficient to determine finally whether the first stage is also thermal; but it is our opinion that it is not. We do not think that the development of a certain quantity of heat in the mixture is essential to the starting of ignition, but rather the development of a certain intensity of ionisation. This intensity of ionisation may be produced by thermal (*i.e.*, thermionic) means; it is probably so produced when ignition is started by a hot wire, and possibly, though not probably, when it is started by a flame; but it may be produced also by other means—*e.g.*, ionisation by collision or the action of ionising rays. The first of these means is probably employed in the spark discharge; the second when the ignition is started by the incidence of X-rays on a metal plate.

We do not quite understand why Dr. Eccles says that his view (*i.e.*, that the development of a small quantity of heat is essential to the starting of ignition) is consistent with the view that "joules per spark" are the determining factor in ignition. It appears to us that the two views are necessarily associated.

A demonstration of the Uses of Invisible Light in Warfare was given by Professor R. W. Wood, of John Hopkins University.

The first device shown was a signalling lamp consisting of a 6-volt electric lamp with a small curled-up filament, at the focus of a lens of about 3 in. diameter and 12 in. focus. This gave a very narrow beam, only visible in the neighbourhood of the observation post to which the signals were directed. In order to direct the beam in the proper direction, an eyepiece was provided behind the filament. The instrument was thus converted into a telescope, of which the filament served as graticule. When directed so that the image of the observation post was covered by the filament, the lamp, when lit, threw a beam in the proper direction. In many circumstances the narrowness of the beam was sufficient to ensure secrecy; but sometimes it was not desirable to show any light whatever, and filters were employed to cut out the visible spectrum. By day a deep red filter, transmitting only the extreme red rays, was placed in front of the lamp. The light was invisible to an observer, unless he was provided with a similar red screen to cut out the daylight, in which case he could see enough to read signals at 6 miles. By night a screen was used which transmitted only the ultraviolet rays. The observing telescope was provided with a fluorescent screen in its focal plane. The range with this was also about 6 miles.

For naval convoy work, lamps are required which radiate in all directions. Invisible lamps for this purpose were also designed. In these the radiator was a vertical Cooper-Hewitt mercury arc, surrounded by a chimney of the ultraviolet glass. This glass only transmits one of the mercury lines, viz., $\lambda = 3{,}660$ A.U., which is quite beyond the visible spectrum. Nevertheless, the lamp is visible at close quarters, appearing of a violet colour, due to fluorescence of the retina. The lens of the eye is also fluorescent. This gives rise to an apparent haze, known as the "lavender fog," which appears to fill the whole field of view. Natural teeth also fluoresce quite brilliantly, but false teeth appear black.

Reverting to the use of the lamps at sea, they are picked up by means of a receiver consisting of a condensing lens in the focal plane of which is a barium-platino-cyanide screen the full diameter of the tube. An eyepiece is mounted on a metal strip across the end of the tube. When the fluorescent spot has once been found somewhere on the screen, it is readily brought to the central part and observed with the eyepiece. The range is about 4 miles, and the arrangement has proved invaluable for keeping the ships of a convoy together in their proper relative positions by night.

MERCHANT SHIPBUILDING AND THE WAR.—In a paper recently read before the Liverpool Engineering Society, Professor T. B. Abell deals with the subject of merchant shipbuilding during the war, and shows how some of the experience gained under war conditions may be utilised to improve efficiency in normal times. Considerable economy in constructional materials may, he points out, be effected without loss of efficiency by reducing the number of sections employed. In the standard ships, for instance, only eight or ten sections were used, whereas for a similar ship of ordinary construction between 30 and 40 sections would be employed. The importance of designing ships for the rapid loading and discharging of cargo is touched upon in the paper, and the importance of making hatches as large as possible is brought out. Another point, which had to be carefully considered in war time, was the provision of the maximum possible stowage space in a vessel of given dimensions, and the matter is of no less importance in normal times for reasons of economy. The damage done by mines and torpedoes to merchant ships has, of course, enabled much experience to be gained as to the effect of watertight subdivision, and this experience may well be applied to the reduction of losses from collisions. Professor Abell concludes that nothing is to be gained by minute subdivision, and that watertight doors should be avoided wherever possible. With regard to the form of ships, the author expresses the opinion that the length of the parallel middle portion has, in some cases, been made greater than is desirable from the point of view of overall efficiency. Fabrication of ships' structures, the author believes, will be almost impracticable under the conditions usually prevailing in normal times, but far-reaching developments, he thinks, may possibly result from the employment of electric arc welding with metal electrodes. One difficulty, however, is to arrange the joints in a large structure, such as a ship, so that the welds will be satisfactory. The aim, in Professor Abell's opinion, must be to secure butt joints of all plating irrespective of the direction of the joint, but at present a horizontal butt joint between two vertical plates is very difficult to make. The best form of electrode for shipbuilding work has still to be settled, and the author concludes that the present need is to discover an electrode which will avoid the use of a slag covering without sacrificing the high quality in the material of the weld. Inspection, he considers, will always be difficult and will have to be very thorough.

SOCIETY OF GLASS TECHNOLOGY.

THE annual meeting of the above Society was held on Wednesday, April 16, in the Applied Science Department of the University of Sheffield.

Mr. W. F. J. Wood, C.B.E., president, took the chair, and presided over a well-attended meeting.

After the annual report of the society had been read, and received with acclamation, the officers for the coming year were elected, Mr. S. N. Jenkinson, M.B.E., becoming the society's new president.

After the formal business had been dealt with, Mr. Wood gave a short presidential address, in which he spoke of the Research Association that had been formed in the glass industry. A provisional committee had been appointed, and at an early date all manufacturers in the industry would be invited to join the Glass Research Association. Substantial promises had already been received, and it was felt that the scheme would be a huge success, especially as it was being looked upon with such favour by the Department of Scientific and Industry Research.

Mr. A. P. M. Fleming, O.B.E., Director of Educator and Research for the British Westinghouse Company, gave a most interesting and instructive account of industrial research in the United States. Many lantern slides were shown of buildings devoted wholly or partly to industrial research.

Sir Frank Heath, Secretary of the Government Department of Scientific and Industrial Research, then addressed the meeting. He pointed out the glass industry had been engaging the anxious consideration of the Government as much, if not more, than any industry in the country since the war began. During the war the department had been enabled to help the industry in many ways, and would do so in the future. There was considerable research still to be carried out, but this would cost money, and take time. He could not help feeling that too much dependence upon State aid indicated an unhealthy condition in industry. It ought not to be necessary for any industry to look outside itself for direct and immediate aid in the conduct of its work. That was not the past of British industry, which was where it is by its own efforts, a fact we were very proud of. It was certain that British industry would have to save itself by organisation, and work from within. There was very great call from other industries besides that of glass for State aid in research. Research was insurance for knowledge, and he appealed to the Research Association to get the best men possible for their work, and then they would be absolutely certain of good results.

Dr. W. E. S. Turner addressed the meeting after an interval had been taken for tea. He emphasised the need for research, and showed how it would advantage small firms as well as the great. He gave several examples where money had been wasted and was being wasted for lack of scientific knowledge and supervision. The chemist, in co-operation with the engineer, was a safeguard in the industry, he appealed for researches in glass on the pure side as well as the applied.

Before the meeting, the Department of Glass Technology was thrown open to members of the society, many interesting and instructive operations being carried out. Mr. J. H. Davidson, M.Sc., F.I.C., showed the casting of a 2-cwt. glass pot.

After the visit of inspection, members of the society had the valuable opportunity of seeing the vacuum casting of a large glass pot. The pot, when finished, was some 38 in. in diameter, and of the hooded variety. The demonstration was carried out by Mr. B. J. Allen, to whom the society owes a great debt for carrying out an operation on so large a scale under rather adverse conditions.

In the evening the society held their first annual dinner in the Grand Hotel, the chief guest was the past-president, Mr. W. F. J. Wood, C.B.E., B.Sc. The other guests present included Dr. Ripper (Vice-Chancellor of Sheffield University), Sir Frank Heath, Dr. F. E. Bradley, Mr. A. P. Trotter, Mr. William Gibbons, Mr. P. W. B. Tippetts, Mr. A. P. M. Fleming, Mr. T. Mortimer Sparks (commercial editor of *The Sheffield Daily Telegraph*), Mr. R. Ainger (commercial editor of *The Sheffield Independent*).

The next meeting of the society will be held in London on May 21, when it is hoped that Dr. Walter Rosenhain, F.R.S., will read a paper on "Refractories Research," carried out at the National Physical Laboratory. On the morning of the meeting members will be given the opportunity to visit the National Physical Laboratory.

SOME WAR PROBLEMS OF PETROLEUM SUPPLY.—In the address on "Some War Problems of Petroleum Supply," which the new president of the Institution of Petroleum Technologists, Sir Frederick Black, K.C.B., delivered on April 15, the manifold administrative, industrial and technical problems were dealt with on very broad lines in a discoursive manner. Sir Frederick has been connected with the fuel supply of the Navy for more than thirty years; he has been Director of Navy Contracts since 1906, and he was for some time during the war, in the interval between Lord Northcliffe's departure and Lord Reading's arrival, acting chairman of the British War Mission in the United States. In his address he referred to tank steamers, oilfields and companies, refineries, shale oils, fuel oils, the coal difficulties caused both over here and in America by transport and labour troubles, the astounding creation of shipbuilding yards in the United States, Diesel engines, cracking and gasoline—being evidently anxious to bestow personal credit in all the quarters in which it is due. One statement may come rather as a surprise, viz., that while the necessity of restriction of coal consumption and of food had been recognised at an early stage, the necessity of conserving petrol had not been so apparent at that stage.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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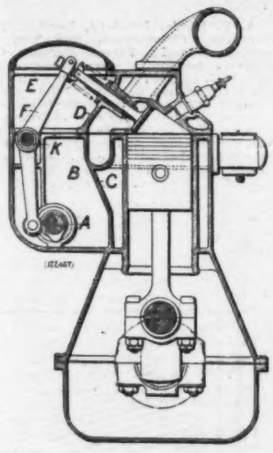
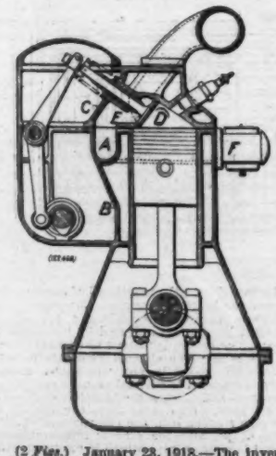
GAS ENGINES, PRODUCERS, HOLDERS, &c.

122,467. T. B. Murray, Scotstoun, and Albion Motor Car Company, Limited, Scotstoun. Internal-Combustion Engines. (2 *Figs.*) January 23, 1918.—The invention provides improved mechanism for operating tappet valves in internal-combustion engines. According to the invention, a usual cam-bearing lay shaft extends along the engine parallel with, to one side of, and above the crankshaft, and is arranged at the lower part of a pocket formed integrally with the cylinder casting. Valve-operating tappet levers, pivoted on a shaft preferably supported from the detachable head at the top of this pocket, descend towards the lay shaft, the cams on which engage their ends, which ends are provided preferably with tappet rollers. Above the shaft on which they are supported, the tappet levers extend upwards and inwards to engage at their upper ends the stems of valves arranged at an angle to the vertical and opening into the combustion space. Preferably inlet and exhaust valves



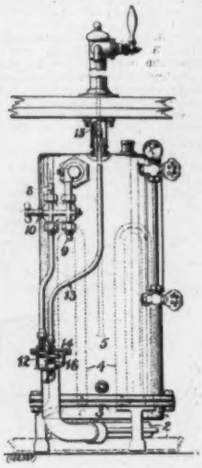
are thus arranged side by side, and there is one lay shaft and one lever-supporting shaft (which, however, may be in several parts). The valve stems and the upper parts of the levers are enclosed in a lateral casing, preferably formed integrally with the detachable head. The valve mechanism is completely enclosed, and the usual cam-bearing layshaft A (driven in usual manner by gearing of any convenient type not shown) lies in the lower part of a lateral pocket B formed integrally with the cylinder casting C. There makes joint with the top of this pocket, at the level of the detachable combustion head casting D, a lateral extension E of that part. In the pocket B, and its extension E, are housed the tappet levers F, rollers on the lower ends of which are engaged by the cams on the layshaft A, while their upper ends are provided with usual adjustable tappets engaging the spindles of the exhaust valves and the inlet valves. The tappet levers are loose upon shafts K. (*Accepted February* 5, 1919.)

122,468. T. B. Murray, Scotstoun, and Albion Motor Car Company, Limited, Scotstoun. Internal-Combustion



Engines (2 *Figs.*) January 23, 1918.—The invention has for its object to provide an improved inlet manifold arrangement cast integrally with the cylinder casting. According to the invention, the inlet manifold of open-topped channel or other easily-moulded shape, is formed along the top of the cylinder casting adjacent to the cylinders, substantially in a straight line, and upon that side of the cylinders on which the inlet valves are. It is closed by the under side of the detachable head with which joint is made. From this channel, simple passages debouch through the detachable head to each inlet valve. A passage (or passages) is also formed to the carburettor, this may either pass upwards through the detachable head more or less downwards through the cylinder body, or more or less horizontally therethrough to the side of the engine remote from the valves. This passage may be at the end of an *en bloc* group, or there may be a passage at each end, or when the engine is of four cylinders *en bloc*, it may be at the centre of the block. The inlet manifold A of open-topped channel section is formed along the top of the cylinder casting B, and is closed by the under side of the detachable head C. It lies on the side where are the inlet valves D, is closely adjacent to them, and communicates with them by passages E formed in the head. The channel-like passage A communicates with the carburettor F by a transverse passage formed in the cylinder casting. (*Accepted February* 5, 1919.)

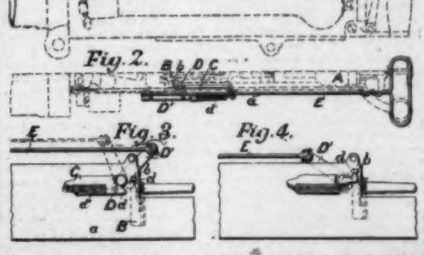
122,597. W. M. Still and Sons, Limited, London, and F. G. Still, London. Gas-fired Water Heating Apparatus. (1 *Fig.*) August 27, 1918.—This invention has reference to gas-fired apparatus for heating water. The boiler, which is mounted on feet above a gas ring 2, comprises a dished base portion 3 formed with a flange and a domed bottom whose horizontal central portion constitutes a tube plate into which is brazed or welded, one limb of each flame tube 4, the ends of the other limbs being outwardly bent and brazed, or welded, into the vertical wall of the base portion 3, as shown. Only two flame tubes 4 are indicated, but it is to be understood that a complete circular row of tubes are employed, the two limbs of each tube lying in the same radial plane with their inner limbs sufficiently spaced apart; the inner limbs may be staggered if desired. Upon the base portion 3 rests the main shell 5 of the boiler. 8 is the gas supply pipe and 9 the water supply pipe, the gas



and water supplies being controlled by a combination lock 10. The water supply to the boiler is regulated by a float valve and the gas supply is regulated by a regulator 12 having the pipe 13 of the actuator 14 connected to the outlet pipe 15. 16 is the valve regulating the amount of gas passing to the jet of the atmospheric gas burner. With the heating surface constituted by inverted U-tubes, as described, the requisite heating of the water will be rapidly effected after the full supply of gas is admitted to the burner, whilst the employment of such tubes enables them to be mounted entirely upon the base portion of the boiler so that they can be readily exposed by removing the main shell after breaking the joints between it and the base portion and between the gas regulator casing and its cover; by connecting the actuator to the draw-off pipe on the outlet side of a contraction therein, as described, the full heating effect of the heating surface is at once obtained upon the opening of the draw-off tap. (*Accepted February* 5, 1919.)

GUNS AND EXPLOSIVES.

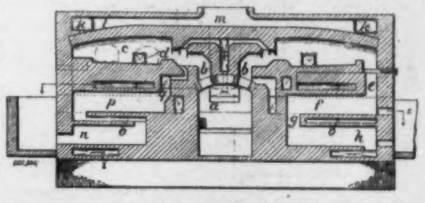
122,555. Sir A. T. Dawson, Westminster, London, and Sir G. T. Buckham, Westminster, London. Machine Guns. (4 *Figs.*) May 8, 1918.—This invention relates to machine guns of the barrel-recoiling type having an extractor or cartridge carrier slidably mounted on the lock. According



to the present invention, a device is provided which, when operated in the event of a stoppage occurring, will cause the extractor to be forced into the firing position so that the defective cartridge can then be fired. A is the mechanism casing of the gun, *a* the left-hand side plate of this casing, B the extractor, *b* the left-hand horn of the extractor, and C the left-hand side cam. D is a pawl pivoted to the side plate *a*, *d* the toe of the pawl for operating upon the horn *b* to force the extractor B to the firing position, and E the pull-rod for operating the said pawl. The pawl D lies within the mechanism casing close to the side plate *a*, and its pivot-pin carries a two-armed lever D_1 disposed outside the said side plate. The upper arm of this lever is connected to the pull-rod E and the lower arm to the forward end of a spring d_1, whose rear end is attached to the side plate. The pawl D normally occupies the position shown by full lines in Fig. 3, with its rear face in contact with the front face of the side cam C, which is cut away to accommodate this pawl. In this position the toe *d* of the pawl lies out of the path of the horn *b* of the extractor and the latter is therefore free to move on the lock in the usual manner during the working of the gun, without the pawl becoming moved. In the event of a stoppage occurring with the extractor in the position shown by Fig. 3, the rod E is pulled to bring the pawl D into the position shown by chain lines in this figure, with the toe *d* in contact with the lower surface of the horn *b*, and a continued pull on the said rod then displaces the pawl to the position shown by Fig. 4, and thereby forces the extractor to its topmost position so as to enable the defective cartridge to be fired and the case extracted in the usual way. (*Accepted February* 5, 1919.)

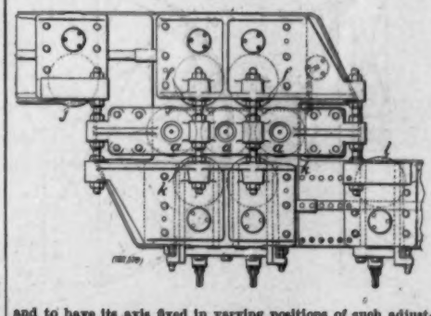
MINING, METALLURGY, AND METAL WORKING.

122,504. A. Smallwood, Highgate, London. Furnaces. (2 *Figs.*) February 2, 1918.—This invention relates to the type of reverberatory furnace in which the heating gases enter the working chamber by way of a horizontal gas passage aligned with said working chamber; in which a recuperator is located below the working chamber, and in which air heated by said recuperator is admitted to the said gas passage from above and below the same. According to the present invention, in this type of furnace the heated air from the recuperator is conveyed to a transverse flue located below the working chamber and communicating with the gas passage from below, from which transverse flue a connecting flue extends to a second transverse flue located substantially on a level with the working chamber and communicating with the gas passage from above. Between the second transverse flue and the horizontal gas passage a vertical ingress part of the horizontal passage occurs, said vertical ingress part being arranged to receive gas from a producer forming part of the furnace. The furnace comprises an elongated structure having a central transversely-disposed gas producer *a*, from which two flues *b* extend upwardly. These flues then extend horizontally in opposite directions longitudinally of the furnace, and communicate with the chambers *c*, which are also arranged in alignment longitudinally of the furnace. On one side of each chamber *c*, charging openings are provided. On the other side of each chamber a slag hole may be provided.



The waste gases egress from the remote ends of the chambers *c* by downwardly-extending damper-controlled flues *e*. These flues *e* extend below the bed of the chamber *c*, at *f*, in a direction towards the central gas producer, and then depend at *g* and extend at *h* in a direction away from the central gas producer, so that the gas is adapted to take a double course below the chamber *c*. Finally, the gas flues communicate with a transverse flue *i*, which communicates with a vertical flue at one side of the furnace; said vertical flue communicates at *k* with a flue *l* in the crown of the furnace. One common flue *l* may be provided in the crown of the furnace over both chambers *c*, and may be in communication with a stack *m* centrally located above the furnace. The flues *e*, *f*, *g*, *h* may be three in number for each chamber *c*, being arranged at intervals across the width of the chamber. Intermediately to these flues, air flues are provided. Two of these air flues extend from the end of the furnace inwardly at *n* towards the centre thereof, between the flues *h*, said two air flues then enter a horizontal air space *o* between the flues *h*, *f*. In this air space the air is adapted to flow in a direction towards the end of the furnace, and said air space then communicates with air flues *p* located intermediately to the flues *f*. In these air flues the air passes towards the centre of the furnace and then flows upwardly into a transverse air flue *q*, from which air flues are provided which communicate from below with the flues *b* extending from the central gas generator *a* to the chamber *c*. (*Accepted February* 5, 1919.)

122,579. H. C. Dickson, Quinton, near Birmingham, and J. W. Lawson, Halesowen. Straightening Rods and Bars. (1 *Fig.*) June 24, 1918.—In machinery for straightening bars, the article to be straightened is successively subjected to the influence of a series of rollers, and after being subjected to this influence, is subjected to the influence of a single roller adapted to be adjusted in a direction longitudinally of the bar,



and to have its axis fixed in varying positions of such adjustment. According to the present invention, the bar is adapted to be treated in a first pass or operation in the manner just described, after which in a second pass or operation the bar is adapted to be treated between the rollers occurring on one side of the bar in its first pass or operation, and a third set of rollers. This third set of rollers may be idle rollers which are located

to the side of the driven rollers remote from that on which the idle rollers appertaining to the first pass are located, and a single roller is provided in conjunction with the second set of idle rollers and is located at the opposite end of the machine so that the bar may in its first pass move in one direction, and in its second pass move in an opposite direction. *a*, *a*, *a* represent three rollers, all of which are adapted to be positively driven. Above the rollers *a*, two idle rollers *f* are located. These idle rollers are located with their axes at positions intermediate to the positions of the axes of the roller *a*, so that a bar passed substantially horizontally between the rollers *a*, *f* comes into successive contact with the five rollers. The rollers *f* are adapted to be adjusted in position towards and away from the rollers *a*. *j* is a single roller which is mounted adjustably in the framework of the machine. After the bar has passed between the rollers *a*, *f* its upper surface comes into contact with the roller *j*. *k*, *k* represent idle rollers similar to the rollers *f*, these rollers *k*, *k* being located on the side of the rollers *a* opposite to that on which the rollers *f* occur. These rollers *k*, alike with the rollers *f*, are adjustable towards and away from the bar. *l* is a roller similar to the roller *j*, but located at the opposite extremity of the machine, so that when in a second pass the bar has traversed the rollers *a*, *k*, it is engaged by the roller *l*. The roller *l*, alike with the roller *j*, being adjustable towards and away from the bar as well as towards and away from the rollers *k*, can be so located as to appropriately treat the bar. (*Accepted February* 5, 1919.)

122,534. Huntingdon Heberlein and Co., Limited, London, and H. C. Bingham, London. Cleaning Gaseous Bodies. (3 *Figs.*) March 5, 1918.—This invention relates to apparatus for use in separating particles of solid or liquid substances held in suspension in gaseous bodies by subjecting the latter to the action of high potential electric discharges. The dust-charged gases are caused to pass through vertically-arranged pipes A which serve as the receiving electrodes. These pipes are suspended from above, but are not insulated. According to the present design, they are attached to carriers D supported on joists F. In the centre of each pipe is suspended an insulated discharging electrode C, which may be an iron chain weighted and anchored at its lower extremity in such a manner as to

Fig. 1.

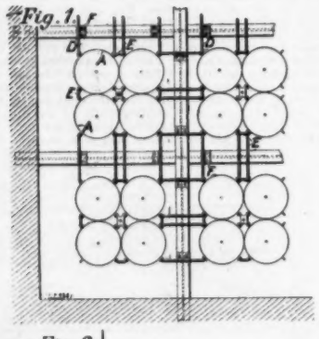
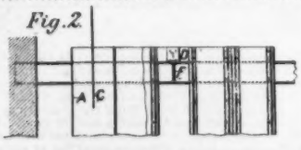


Fig. 2.



maintain it throughout its length equi-distant from the inner surface of its surrounding pipe. The pipes A are divided longitudinally into four segments, flanged and bolted together. Each pair of longitudinal flanges forms a stiffening rib, and these ribs may be further stiffened by the insertion of flat bars, or by the addition of T-irons, whereof one member is inserted between each pair of pipe flanges. The stiffening ribs, whether with or without the reinforcements described, may, moreover, be utilised for the attachment of distance or steadying pieces E for maintaining the pipes in their proper relative positions when erected in groups. In assembling the pipes in the construction of a battery they are arranged in groups of four close together, sufficient space being left between each group to afford access for inspection or repair. (*Accepted February* 5, 1919.)

MOTOR ROAD VEHICLES.

122,320. Alldays and Onions Pneumatic Engineering Company, Limited, Birmingham, and C. E. Simms, Birmingham. Wheels for Motor Tractors. (7 *Figs.*) March 13, 1918.—The invention consists of improvements in wheels or motor tractors. According to the said invention,

Fig. 2

Fig. 1.

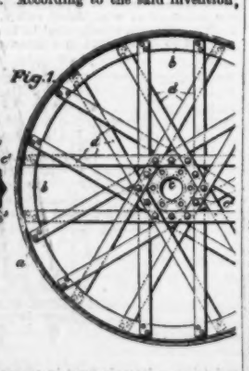
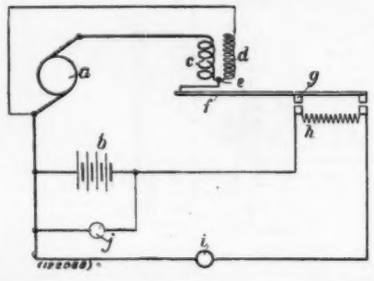


Fig. 3.

a wheel rim is taken preferably of the type having on the inner side of the periphery of the felly two angle-iron rings or two T-shaped rings to the vertical flanges of which the outer ends of the spokes are connected, and a hub for the wheel is provided with spoke flanges of a hexagonal or other polygonal shape and with steps or shoulders parallel with the edges of the said hexagonal or polygonal flanges, the said hub being preferably made by casting. The stepped or shouldered parts constitute projections on the outer sides or ends of the hub and form seats for the edges of the middle portions of the spokes, which are made of bar iron or strip metal. Each bar iron or strip metal spoke is of such a length as to permit its ends to be riveted to the vertical flanges of the angle iron or T-shaped rings on the interior of the rim, or of being shaped to permit them to be riveted to the felly when such inwardly-projecting flanges are not provided. The angles of the hexagonal spoke flanges at one side of the hub may not coincide with the angles of the hexagonal spoke flanges at the other side or end of the hub. *a* is the cylindrical rim and *b*, *b* are angle-iron rings fixed to the inner side of the rim *a*, the vertical flanges of the rings *b* being separated some distance apart. *c* is a cast hub, shown detached in Fig. 5, having hexagonal spoke flanges c^1, c^1 at opposite ends. Each spoke flange has a stepped part c^2 on its outer side, which steps constitute seats for the edges of the middle portions of the spokes *d*. The spokes are made of strip metal. The spokes *d* are disposed in pairs parallel to each other, the ends being riveted to the vertical flanges of the angle-iron rings *b*, and the middle portions being bent so that they can be seated on the stepped portions of the spoke flange on the side of the wheel opposite to that of the flanged ring *b* to which the ends of the spokes are fixed. Alternate pairs of spokes are riveted to the angle-iron ring *b* on one side of the wheel, and the intermediate spokes are riveted to the angle-iron ring *b* on the other side of the said wheel. The outer sides of the spoke flanges c^1 have on them a series of inclines to permit the spokes *d* to have a continuous or unbroken bearing against them at the parts where the said spokes are slightly bent to permit the requisite interlacing thereof. The spokes are fixed to the spoke flanges preferably by rivets. The hub may have near its outer end a series of bosses or lugs c^3 through holes in which bolts or screw pins are passed for fixing the wheel to the flange or the like on the driving axle on which the wheel is keyed, or the wheel may be keyed only or otherwise fixed on the axle. (*Accepted January* 29, 1919.)

122,088. A. H. Midgley, Acton Vale, and C. A. Vandervell and Co., Limited, Acton Vale. Motor Car Lighting Arrangements. (1 *Fig.*) March 22, 1918.—According to the present invention, use is made of the automatic cut-out usually employed in electric lighting systems on motor cars and the like, or of an equivalent device, for automatically controlling the current flowing through the head lamp, or other lamp, in such a manner that when the vehicle on which the electric lighting system is mounted stops, or when its speed is reduced beyond a certain limit, the current flowing through the lamps is automatically reduced. The armature of the dynamo *a* is arranged in series with the battery *b*, and the series winding *c* of the automatic cut-out, whilst the shunt winding *d* of the latter is arranged as usually in series with the series winding thereof across the brushes of the armature. The point of connection *e* of the series and shunt windings of the automatic cut-out is connected to the lever *f* of the latter, which lever is provided with two contacts *g* adapted to short circuit a resistance *h* when the automatic cut-out is energised, the said resistance being



arranged in series with the head lamp *i* across the battery *b* one pole of which is connected to the one brush of the machine whilst its other pole is connected to one end of the said resistance. When the automatic cut-out is in operation, the battery *b* is connected across the armature of the dynamo *a* through the automatic cut-out, and the head lamp *i* receives the full current, the resistance *h* in series therewith being short-circuited by the two contacts *g* provided on the lever *f* of the automatic cut-out. When the speed of the machine falls below a certain limit, or when the dynamo is stopped, the automatic cut-out becomes de-energised and the short circuit of the resistance *h* is removed, whereby the head lamp *i* is caused to receive a smaller current from the battery *b* as compared with the full current passing through it whilst the dynamo *a* is running under normal conditions. The tail lamp *j*, or other lamps provided in the lighting installation, may be arranged across the battery *b* or be adapted to be operated in the same manner as the head lamp *i*, that is to say through the intermediary of a resistance arranged in series therewith and adapted to be short-circuited by the automatic cut-out. (*Accepted January* 22, 1919.)

STEAM ENGINES, BOILERS, &c.

119,653. The British Westinghouse Electric and Manufacturing Company, Limited, Westminster, London. (*Assignees of R. N. Ehrhart, Edgewood Park, Penn., U.S.A.*). **Steam Condensers.** (2 *Figs.*) September 29, 1917.—This invention relates to a new and improved condenser of the jet type. According to the invention, the improved condenser is formed with a substantially annular condensing chamber having a discharge port in the bottom thereof and an annular inlet port in one side, and nozzles are provided for discharging jets of cooling liquid across the condensing chamber in a radial plane towards, and in a substantially tangential direction with relation to the inner substantially annular wall of the chamber. The turbine, the exhaust end portion of which is shown in Fig. 1, includes a rotor element 3 mounted on a shaft 4. The casing 6 of the turbine terminates in an exhaust chamber 7, which is equipped with cooling water delivery nozzles 8 and water discharge passages so arranged that the exhaust chamber in effect constitutes a condenser for the steam issuing from the turbine. A water-box 9 surrounds the chamber 7, and delivers water to the nozzles 8. The nozzles are so arranged that they deliver a mass of separate drops or spray as close to the last row of blades as is permissible without discharging water into the blades. The inner substantially annular wall of the condensing chamber, which is constituted by an inwardly-projecting central portion 11 of the end wall of the turbine, is formed to a channel shape in cross-section. The upper two thirds is formed to a circular shape, and gradually merges into the lower part which extends downwards to an edge near the bottom of the chamber 7, as shown in Fig. 2. The nozzles 8 are divided into two groups, each of which is located on one side of the vertical plane passing through the axis of the turbine. The nozzles of each group are inclined downwardly, and are so spaced that the water delivered from them forms a substantially continuous curtain into and through which steam issuing from the blades must pass. The water discharged from the upper nozzles of both groups is received by the trough-shaped upper part of the inner wall of the chamber 7 and that discharged from the lower nozzle impinges against the lower part of the wall, which is extended downwardly nearly

Fig. 1.

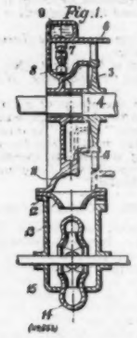


Fig. 2.

to the bottom of the chamber 7. The flange 11*a* of the inner wall is located in close proximity to the turbine rotor, and forms an apron which prevents the water from splashing against the blades or into the working passages of the turbine. The water discharged from the chamber 7 passes through convergent cone 12 into a condensate well 13. A centrifugal pump 14 is so located that its intake ports 15 are within the well 13. (*Accepted February* 5, 1919.)

122,232. A. F. Hinds, Finchley, London, T. Stinchcombe, Brampton, Chesterfield, and The Chemical Engineering and Wilton's Patent Furnace Company, Limited, Hendon, London. Steam Boiler Furnaces. (3 *Figs.*) January 9, 1918.—This invention relates to furnaces for steam boilers of the kind wherein no grate bars are used and the fuel is placed in a mass upon a perforated hearth through which air is forced. A furnace made in accordance with this invention is characterised in that the space below the hearth is provided with a chamber divided into transverse compartments into which air is delivered at the same or different pressure, the air issuing through the holes in the surface of the hearth to the fuel. *a* is the front of the boiler, *b* the steam chest, *c* the water

Fig. 1.

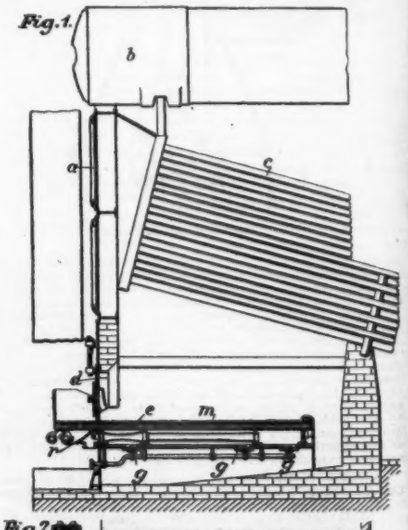
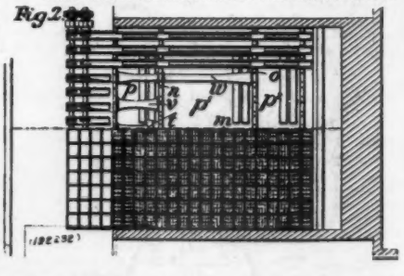


Fig. 2.



tubes, *d* the furnace door, *e* the hearth, all of known construction. The space below the hearth is enclosed, forming a chamber, the bottom of which is provided with gratings *g*, *g*, *g*, adapted to be opened and closed by shutters operated by handles in any well-known manner. The hearth is formed of channel irons carrying perforated plates *m m*. The channel irons are perforated and adapted to be reciprocated in any well-known manner. The chamber below the hearth is divided transversely by partitions *n*, *o*, into compartments. Below the hearth is disposed a hood *r*, forming the air inlet. Extending from the hood *r* are pipes *t*, *v*, *w*. The pipe *t* opens into the compartment *p*, the pipe *v* into compartment *p*1, and the pipe *w* into compartment *p*2. Within the hood is a steam pipe which is provided with nozzles which extend into the pipes *t*, *v*, *w*. (*Accepted January* 29, 1919.)